THE TEACHING OF

GENERAL SCIENCE

PART II

SCIENCE MASTERS' ASSOCIATION

LONDON
JOHN MURRAY, ALBEMARLE ST., W.

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Part I. Interim Report of the Sub-Committee.

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SCIENCE MASTERS' ASSOCIATION

FINAL REPORT OF THE SUB-COMMITTEE
APPOINTED IN 1935

ADOPTED BY THE GENERAL COMMITTEE IN 1938

LONDON
JOHN MURRAY, ALBEMARLE STREET, W.

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L. G. SMITH, Headmaster of Trowbridge High School for Boys; Chairman of the General Committee in 1937 (5).

Mr. C. J. R. WHITMORE, M.C., H.M.I., was present in an advisory capacity at all the meetings of the Sub-Committee.

(5) Indicates members of the General Committee in 1935.
(8) Indicates members of the General Committee in 1938.

* Indicates members of previous General Committees.

2. FOREWORD

THE General Committee of the Science Masters' Association approves and adopts this Report because it agrees that school science teaching should not rest on a narrow basis, that General Science meets this requirement, and that it can be taught along the lines shown herein.

The Committee places on record its high appreciation of the immense amount of time and concentrated effort spent by the members of the Sub-Committee in preparing the Report; their labours have been prolonged and unremitting, and their findings place in their debt not only the Association but Education as a whole.

Signed on behalf of the Committee,

W. G. GREAVES (*Chairman*).

S. V. BROWN (*Secretary*).

3. INTRODUCTION

FOUR years have passed since the Sub-Committee, which is now making its final report, was appointed by the Committee of the Science Masters' Association to consider the problems presented to teachers in Secondary Schools by the introduction of courses in General Science as a constituent of general education, and to make specific suggestions about the aims to be kept in view. They were asked to consider the basic principles of the subject, an appreciation of which should be inculcated; the material to be included in such courses; methods of development and treatment of the material; and time-table requirements at different stages.

Towards the end of 1936, an Interim Report on these lines was presented to the General Committee, by which it was unanimously approved and adopted. It was then published for the Association by John Murray under the title of *The Teaching of General Science*. The Interim Report included an Introduction, in which the general principles contained in the above-mentioned terms of reference were examined at some length, and also a detailed scheme of work, called the Minimum Syllabus, in which it was shown how the principles might be applied in schools where Science was given but a meagre allotment of time.

The present Report, offered with full unanimity on the part of its compilers, completes the task which was set to the Sub-Committee. It will be found to follow the lines of the former one in dealing first with general matters, and then presenting a detailed scheme of work adapted for schools in which Science is given a reasonable amount of time in the curriculum.

After the publication of the Interim Report, Mr. Archer Vassall and Mr. A. J. Price retired, and Mr. G. W. Olive was appointed to the Sub-Committee: otherwise the personnel remained unchanged and Mr. C. J. R. Whitmore, H.M.I., continued to render great assistance by attending the meetings in an advisory capacity. The list of those who have contributed to the two Reports is, however, far larger than that of the Sub-Committee itself, whose members have throughout received the sympathetic help and encouragement of the General Committee, and whose frequent appeals for aid, both to many members of the Association and to other experts, have always met with a ready response. The Sub-Committee is deeply conscious of its debts to all its friendly helpers.

In January, 1937, shortly after its approval and adoption by the General Committee, the Interim Report was discussed at the Annual Meeting of the Association in Manchester. Of the four hundred members present, not one voice was raised against General Science as an ideal, and many expressed their agreement with the guiding principles set down in the preamble. Divergences in detail there certainly were, and these will be considered later, but there can be no doubt of the support accorded to the general proposals, which also seem to have been well received by various branches of the Association, by the Association of Women Science Teachers, and by the Science Panel of the Association of Assistant Mistresses (*School Science Review*, Vol. XIX, No. 73, page 134). At the Manchester meeting, Professor J. S. B. Stopford's Presidential Address (*S.M.A. Report* for 1936) came opportunely on the day before the discussion of the Interim Report, for although he was unaware of the findings of that publication, his proposals agreed very closely with them.

A year later, Sir Cyril Ashford, presiding at the Annual Meeting in January, 1938 (*S.M.A. Report* for 1937), spoke in high praise of the Interim Report; he said that the majority

of the members of the Association were converted in principle to General Science, and that he hoped that the whole body would soon adopt it in practice. Sir William Bragg, who preceded Professor Stopford as President of the Association, has also spoken with equal approval of the Interim Report.[1]

These are recent examples, but again and again have the distinguished men of science and of letters who have presided over the Association urged that scientific education should rest on a broad foundation. That, too, has been the attitude of the Board of Education for many years. The Investigators who, in 1931, enquired into the School Certificate Examinations reported in a similar way; and so did also the Committee appointed by the Prime Minister in 1916 to enquire into the position of natural science in the educational system of Great Britain.

To the foregoing evidence of a widespread desire to broaden the basis of science teaching in the Secondary Schools there should be added the fact that, for twenty years and more,[2] the annually elected Committees of the Science Masters' Association have steadily shown interest in the generalised teaching of the subject in the early stages (*T.G.S.*, pp. 7, 8). In regard to this, there has indeed been a consensus of well-informed opinion, both within and without the Association. How is it then, it may be asked, that General Science is not yet taught in our schools as a matter of course? That is a question which it may be profitable to examine immediately at some length.

[1] *Science in Schools.* An address at a Conference of the Essex Extra-Metropolitan Association of the National Union of Teachers, October, 1937. G. Bell & Sons, 1938.

[2] See page 6 of *The Teaching of General Science*, the title under which our Interim Report was published by John Murray (2*s*. 6*d*.). Hereafter, that publication will be referred to briefly as *T.G.S.* The "*School Science Review*" will be called *S.S.R.*, and the *Science Masters' Book*, *S.M.B.*

4. ADVERSE FACTORS

One factor which has operated against the introduction of General Science, though it is less potent now than in the recent past, is what may be termed the matriculation cult. Much has already been written in other places about the restricting influence which this powerful agency has exerted on the general education of pupils in our Secondary Schools. The essence of the case is that although matriculation is nothing but a label to indicate that its bearer has qualified in those parts of certain subjects which University Statutes demand, yet employers and others have been so dazzled by the label that they have failed to realise that the items enumerated thereon may not be the best for their purpose. Be that as it may, the fact remains that the label was, and in some cases still is, demanded; and, as a result, the true educational needs of the majority of our secondary school population become subjugated to those of the small minority who would use the label for the purpose for which it was originally intended. Unfortunately that is not the end of the story so far as Science is concerned, for the system of awarding matriculation for a certain number of credits collected by the candidate tended to lead schoolmasters to select teaching material for its credit-winning rather than for its educational value. The examination urge acted against the introduction of any material not required by the examiners and narrowness was thereby encouraged. Another powerful influence in this unhappy history is the University scholarship. If matriculation provided the bricks with which this structure of conservatism and narrowness was built, the University scholarship was the keystone which locked it immovably.

The papers which are set for these scholarships are of a very specialised kind and the standard is so high that, for a candidate to be successful, he must already have done a large proportion of the work which is commonly required at the Universities for a first degree. It is at least doubtful if the overlapping of the functions of School and University make for efficiency in general, even when it is viewed from the side of the University, and in the School the result may be disastrous.

Setting aside the important question of whether intensive specialised training, in a spirit of competition, is good for adolescents, let us enquire into the practical effects of the present system of scholarship examinations in Science. When the able son of parents of moderate means passes his School Certificate examination, he may have to decide whether he will leave school at about sixteen years of age or will continue his education, possibly in the hope of winning a scholarship to a University. For an able boy of sixteen years of age, there are many outlets in industry, in commerce, and even in the professions. Should he, however, decide to prepare for a scholarship and eventually fail to get one, his immediate opportunities might not then appear to be much better than they were at an earlier age, and he would have lost some seniority. Parents are not always in a position to take the longer view that an extra year or two of school life, the value of which for many boys is apparent to every schoolmaster, may more than compensate for this loss. Exaggerated importance therefore becomes attached to the winning of scholarships, which becomes the main occupation of both boys and masters. But the scholarship papers in Science are so very specialised, chiefly in Physics and Chemistry, that many masters are afraid that if a boy takes General Science in his School Certificate examination he may be at a grave disadvantage compared with those who have studied only the physical sciences from a very early age (*S.S.R.* XIX, 76, p. 597). This fear may not be well

founded, for there are examples both of schools where General Science is taught and the record for winning scholarships is good, and also of individual boys who have done brilliantly at Science although they began to study the subject only after passing the School Certificate examination; yet the fear exists and it exerts a profound influence. So the work is specialised from the very beginning, and it is usually the biological side of the subject which is neglected.

The evil effects are carried further even than this, for if it is important for an individual to win a scholarship, it is equally important for a science master to gain a reputation for "getting scholarships" for his boys; otherwise the aspirants will choose some other subject for study. The educational faith of the master may incline towards General Science, but he dare not act accordingly. Thus it is that, in many of our schools, the deciding factor with regard to the nature of the work in the Sixth Forms, and even below, is not whether it is good for the minds of the boys, but whether it will lead to the winning of scholarships. Although it is not impossible to amalgamate these factors in a satisfactory manner, there is no doubt that the influence of the scholarship system has been strongly opposed to the introduction of courses in General Science.

In writing as we have done above, we are not trying to shift the responsibility to other shoulders, for those who are in authority at the Universities and on examining bodies are as amenable to reason as anyone else. The blame is probably ours for not putting facts clearly and insistently before them. We must earnestly strive to change the present scholarship examination system, with its absurdly high standards for work in specialised branches of subjects. To continue to accept things as they are is quite unworthy of an Association such as ours.

If we push our enquiry a stage further to seek the reason for the high degree of specialisation in science which makes its influence felt through the Universities and into the schools,

we are forced to admit that this specialisation of function is a characteristic of the modern world. With the rapid growth of knowledge, the whole of learning cannot remain the province of any one man ; and when it is realised that over a million papers a year are published in science and technology alone, it becomes clear that a very high degree of selection of material becomes essential. This leads to what has been termed "professionalism in knowledge."

"This situation has its dangers. It produces minds in a groove. Each profession makes progress, but it is progress in its own groove . . . the remainder of life is treated superficially with the imperfect categories of thought derived from one profession. . . . In short the specialised functions of the community are performed better and more progressively but the generalised direction lacks vision." [1]

By the very nature of his work the professional must of necessity cut a groove, but the danger is lest these grooves be cut at random and out of all relation to one another. Their direction should be maintained by a constant realisation of their function and place in a general scheme, an achievement possible only when the professional mind appreciates the value and the possibilities of co-ordination. Such a mind cannot have attained maturity in a meagre environment of specialised abstractions, starved of the realisation of other values and points of view. It seems reasonable to demand that the future specialist in some narrow field of science should have at least a nodding acquaintance with the basic principles of allied studies; for whilst intensive specialisation may be a necessary characteristic of his mature thought, it is both unnecessary and undesirable, even for him, at an earlier stage. The narrowing and stultifying influence of this specialisation is seen only too often in science masters themselves, who thus become another factor—possibly the most powerful—in maintaining its stranglehold in the schools. To

[1] Whitehead, A. N., *Science and the Modern World*, Cambridge, 1925, pp. 244–5.

quote from the last report[1] of the Board of Education on the teaching of science in secondary schools:

"This being the general character of the degree courses, few teachers are found who have interested themselves in sciences other than Physics and Chemistry which they learnt at school and studied at the Universities. Among the teachers in the schools visited there are two men who are research Geologists, and one man who edits an astronomical journal—but these are exceptions to the general rule. It is very rare to find teachers who are willing to pursue a science subject which has not formed part of their University course. . . ."

Although this conclusion was reached with special reference to work in advanced courses, and although the Report in which it was published is somewhat out of date, we feel that we should state quite clearly our conviction that much of the opposition raised to the work we suggested in our Interim Report (*T.G.S.*) has come from science masters who, consciously or unconsciously, are influenced unreasonably by the narrow nature of their training. We are strengthened in this view by having before us the evidence of a teacher of Physics who is afraid to try to teach even the Chemistry of our Minimum Syllabus (see *T.G.S.*) lest it should prove to be beyond his ability to do so. Yet the man who knows his subject best is not always the best teacher of it, and boys are as willing to learn with a man who admits his limitations as they are from one who always speaks with authority. Admittedly, the case of this witness is an extreme one, both of specialisation and of diffidence, but it gave us cause for reflection and here we shall quote his own words:

"I feel," he writes, "that a certain amount of the opposition to General Science may be due not to the principle nor to

[1] B. of E. Report of an enquiry into the conditions affecting the teaching of Science in secondary schools for boys in England. (Reprinted 1927, p. 8.)

any particular syllabus, but to the fact that specialists in one subject feel a lack of confidence in dealing with other subjects. Few of us like to admit this, however, and it is a tempting alternative to attack the whole idea."

The opinion expressed above confirms us in the conclusion, to which we have already come from other evidence, that the fear of loss of prestige underlies much of the opposition we have met.

5. CRITICISM OF THE INTERIM REPORT

We have said above that, whereas a large measure of acceptance was accorded to the thesis of our Interim Report, numerous objections were raised to the way in which we suggested that practical effect might be given to the principles by which we were guided. We must now face those objections.

Some of those who criticised our previous proposals do not seem to have appreciated the difficulties under which we laboured owing to our deliberate decision to provide first for schools, or parts of schools, where only four periods a week are allotted to Science in the pre-certificate stage. We believe (*T.G.S.*, p. 21) that we were wise in recognising the fact that there are many such schools and that we were right in trying to help them first of all. To pretend that an adequate survey of the meaning and content of modern science could be made within so short a time was far from our minds. The boys in such schools are, we think, at a grave disadvantage compared with those in schools where considerably more time is given to the subject, and it must be expected that their scientific education will lack either breadth or depth. We decided that depth rather than breadth should be sacrificed; and if that is kept clearly in mind there is no need for the teaching to lack thoroughness. Unfortunately many have confounded depth with thoroughness, and there is still much confusion of thought about this question, to which we shall return almost immediately. After all, one can study a map of England as thoroughly as a six-inch map of a parish. However that may be, our hope is that the subject matter of our Minimum Syllabus, and our methods

of approach to it, will appeal so strongly to those who are in authority that they will be more generously inclined towards Science than they have been in the past. They may be willing to allot more time to a course which is designed to enable boys to take an intelligent view of many aspects of their environment than they do, for example, to the modicum of introductory Chemistry, Heat and Light, which, in so many cases, is the only kind of elementary science which they have considered possible in a school curriculum.

Sir Richard Gregory defines education as the deliberate adjustment of a growing human organism to its environment. If he is right in doing so, a selection such as ours should be of more use than most of the material traditionally employed for the teaching of science. At least we can claim, for every item in our Minimum Syllabus, that a reasonable answer can be given to the question which Sir Cyril Ashford, as our President at the Annual Meeting of 1938, said should constantly be put by the teacher to himself, "Of what use is this to the boy I am teaching?" When we look back at the Minimum Syllabus of our Interim Report and remember the limits for which it was designed, we find that there is little or nothing in it which we would alter.

It is to be hoped that the above words, written in explanation, will not be taken to mean that we have been quite insensitive to criticism. That is far from being so, for some of the objections which were raised against our Minimum Syllabus, and would have been valid had that been our final word, have not been without influence upon our later decisions. Indeed, in introducing the present report, we shall deal with the chief criticisms of the interim one and shall show how far we have been able to meet them, now that we are assuming that there is more adequate time for the teaching.

The most general objection to the teaching material which we provided is that it is too copious. That has found frequent expression in the pages of the *School Science Review* (see

S.S.R., Vol XIX, No. 73, p. 134 and elsewhere). In reply to this, we would state that there is no lesson in our schėdule which has nót been tried in practice by one or other of us within the allotted time. Moreover, we find that the pupils who have been taught in this way have as good, or nearly as good, a grasp of the meaning and purport of the many principles which are brought to their notice as have others who have been trained in a much more restricted field. *We would reiterate that the syllabus which we compiled was designed as a guide for teachers, and not as a prescription for examiners.* Many of the items were included only to indicate the lines along which a master might profitably direct the thoughts of his pupils; a good teacher would doubtless add still more by way of passing reference. No one denies the value of information which is imparted in this way, contributing as it does to the main flow of thought. It is, indeed, essential to the vitality of the work, though it may be of little value for examination purposes. But if everything is taught with one eye on an examination syllabus, the teacher's view is distorted and the picture he presents becomes unsatisfactory. Some of our critics seem to think that no knowledge is of use unless it is readily available, in essay form, under examination conditions: a view from which we dissent most strongly.

Others, while agreeing with what has been written above, yet think that the syllabus is over full. So it may prove to be in practice, unless they are willing to change the technique of their teaching. If, for example, the mention of lenses calls half a term's work to their minds, we would ask them to consider what is essentially of value about lenses which may be taught effectively and thoroughly in a much shorter time. Only by self-criticism of that sort are they likely to attain a *tempo* which accords more closely with the natural desires of children in satisfying their curiosity. When they first come to school, boys are avid for knowledge, but they are easily nauseated by too monotonous a diet. Playwrights

and authors strive above all things to maintain interest, and anyone who has taken children to a cinema cannot fail to have noticed their amazing memory of fleeting scenes. It is possible that we, who are sheltered by permanent scholastic appointments, have something to learn from the art of those whose livelihood depends upon their ability to grip their audiences. We science masters are fortunate in having a really fascinating story to tell. Let us always be asking ourselves whether we tell it well, suiting our pace to our youthful hearers; or whether we do not often let the story drag and interest subside. It is bad practice in teaching to dwell too long on any one topic and it is part of the teacher's art to know when he is exceeding the optimum limit. In some instances, perhaps, the optimum may be greater than the allowance we made in our Minimum Syllabus, but it is certainly much less than in customary practice, for we all incline towards pedantry, the desire to say everything about something, towards which the examination bogey still further bends us.

It may, however, be asked, are we never to get well below the surface of any part of our field of study? The answer is Yes (see *T.G.S.*, pages 26 and 27), but some of us will be interested in drains, some in planting trees and some, we fear, just in digging; so we refrained from specifying any definite parts of our syllabus for this more intensive work and left it to individual choice. The time for carrying it out would have to be filched from that which we allotted to other topics, or as we put it, "One may rob Peter to pay Paul, provided that Peter is left with enough to live on."

Those who have criticised us on the foregoing lines will be glad to notice that although the time for which we are now providing in the Extended Syllabus is greatly in excess of that in the Minimum one, 840 school periods instead of 480, we have introduced comparatively little new work of an entirely different kind. This we have contrived to do,

not by altering the contents of the lessons which we scheduled previously, but by providing more of somewhat similar material and by allowing more time for general revision (see p. 22). We have dug a little more deeply and we have widened our trenches considerably.

Before we leave this major objection, that our Minimum Syllabus was overloaded, we cannot refrain from a thrust at those who sneer at General Science as a soft option. Let them try it and see if it is soft for the teacher. If it proves soft for the taught, that is the fault of the teacher and not of his material. A debater would also observe, in this connexion, that "too much stuff" and "soft option" pull the scales of criticism in opposite directions. The fact that both objections have been made seems to indicate that we have not been altogether unsuccessful in our attempt to achieve a fair balance between them.

6. THE POSITION OF CHEMISTRY

> Nothing destroys the powers of general observation quite so much as a life of experimental science.
>
> *The Food of the Gods*, H. G. Wells.

ONE of the most remarkable traits in the character of an educated Englishman is his faith in the training which has made him what he is. It would be interesting, though perhaps unprofitable, to enquire into the reason for this; but certain it is that, just as it is usual for a man to "believe in" his School and his University, and even to wear distinctive dress in order to acquaint the world of the fact, so a classicist will believe in classics, a mathematician in mathematics, a physicist in physics, and, as will be seen below, a chemist in chemistry.

Since the publication of our Interim Report, letters from teachers of Chemistry have appeared in the *School Science Review*[1] to say that we had shown scant courtesy to their subject. One of the correspondents could not help thinking that the interests of Chemistry must have been less strongly represented on the Sub-Committee than those of the two other subjects—as if we had behaved like Westminster boys in their grease for the pancake. His supposition, which was quite wrong, would probably have never been made had his care, like ours, been more for the interests of the pupils than for those of a special subject. Our method of working was fully described in Part I of the *Teaching of General Science*, so that it is unnecessary to traverse the ground again,

[1] Vol. XVIII, No. 72, pp. 594 *et seq.* and Vol. XIX, No. 74, pp. 299 *et seq.*

except just to reaffirm that nothing was included in, or excluded from, the syllabus because it could be classified under the heading of Chemistry. We have, it is true, found some welcome support amongst the chemists (*S.S.R.*, XIX, 74, p. 299), but it is equally true that most of the sectional objections to our proposals came from those whose special interests lie in that branch of our subject.

The most arresting piece of criticism of the sort we are now considering (*S.S.R.*, XVIII, 72, p. 473) was that we had neglected the quantitative aspects of Chemistry. As the points of our reply to this article, which all who are interested should read, are involved in some remarks printed a little further on in this Report we shall not now dwell upon that matter. We do however wish to say, at this stage, that here also we found ourselves hampered by the exigencies of time; and that when we came to consider the merits of all the possible teaching material according to the criteria upon which we had decided (*T.G.S.*, p. 20), the suitable chemical material proved to be less than that which could be classed as physical or biological. Even so, the proportion of time we allotted to Chemistry is more than that suggested by the Panel of Investigators [1] which was appointed a few years ago by the Secondary Schools Examination Council to enquire into the School Certificate Examination.

This question of our apportionment of time to Chemistry caused great anxiety in the minds of some members of the Institute of Chemistry, as a perusal of the *Journal and Proceedings* (1937) of the Institute and of the *School Science Review* (Vol. XVIII, No. 72, p. 595) will clearly show. Eventually we received a communication to the effect that the Council of the Institute "having considered the real purpose of science teaching in schools—whether it is to inform the

[1] *The School Certificate Examination*, H.M. Stationery Office (1932) 2s. 6d.

pupil with the maximum number of useful facts, or to educate him in generalisations based on precise measurement and the critical assessment of evidence—regards the latter objective as much the more important." On these grounds, the Council pleaded for more time for Chemistry than was allotted in our Interim Report, since the subject "permits the pupil to make with his own hands crucial experiments leading to important conclusions of general significance."

It may well be doubted, however, whether the dilemma propounded by the Council of the Institute does, in fact, face teachers of science. Certainly we have never felt that we had to choose between teaching useful facts and educating in generalisations. We have always envisaged our task as being that of discovering ways of teaching useful facts in order to inculcate an understanding of generalisations and to develop the power of applying these to new situations.

It is now known that such spreading of specific training does not occur as readily or as automatically as was once supposed (*T.G.S.*, p. 13.) Our doubts regarding this point led us to conclude that "of all the claims made for the inclusion of Science in a school curriculum, the strongest undoubtedly is that which stresses the cultural value which the subject possesses" —an opinion to which the Association of Women Science Teachers gave ready assent.

Within the expression "cultural value" we certainly intended to include understanding of the scientific method and appreciation of the scientific mood which the study of science will help to foster. It seems probable, then, that in this matter the divergence of opinion between science masters and the Council of the Institute may be less marked than would appear at first sight and may have been due to some misunderstanding of what our proposals are.

It would, perhaps, be well to ask at this point: at what generalisations would it be reasonable to expect boys of less than sixteen years of age to arrive, as a result of experiments made by their own hands and involving precise measure-

ments and the critical assessment of evidence, during their study of Chemistry?'

If one asks the same question with regard to Physics, the answer is comparatively easy to make. Boyle's law; Hooke's law; Archimedes' principle; Faraday's laws of electrolysis; Ohm's law; these are all examples of principles or laws which may be established quickly in a young pupil's mind, with the help of work done by his own hands. So it happened that, when we wished to inculcate the idea of the quantitative basis of our subject as a whole, we turned to Physics as offering the best medium for this purpose.

What generalisations has Chemistry to compare with those mentioned above as suitable educational material for boys—the Conservation of Mass; the laws of constant, multiple and reciprocal proportions; and the law of Gay-Lussac, perhaps? But if these are to be reached as the result of crucial experiments, made by the pupils themselves, much time is required. What, moreover, is to be done with them when they are established? They do not lend themselves to direct everyday applications as readily as do the physical principles and laws mentioned above. In themselves, they must appear to young pupils as comparatively useless abstractions, unless the story is carried further to Dalton's hypothesis and to Avogadro's, and so to the foundation of the atomic and molecular theories. Very few boys below the age of sixteen years can follow a line of argument so far as that, even if their minds are not fairly fully occupied in other ways. No one denies the value of the study of the basic principles of chemistry which are mentioned above, at a stage when specialisation begins; but to have introduced more into our Minimum Syllabus, with its limited time allowance, would, we think, have been an error of the worst kind.

It is pleasant to be able to turn at last from points of controversy to those of agreement. For some of those who, like Professor H. V. A. Briscoe (*S.S.R.*, XVIII, 72, p. 595), have criticised us most strongly on sectional matters are

yet whole-hearted advocates of the extensive adoption of General Science as a School Certificate subject. Now that we are budgeting for schools in which more adequate time is allotted to Science, we find ourselves able to increase the proportion which we suggest should be devoted to chemical ideas. It will be seen later that we are proposing to give considerable latitude of choice in teaching material and, in effect, that we are making it possible for those who follow our suggestions to devote a third of their teaching time to topics which may be classed as purely chemical. We have introduced quantitative work which will doubtless go far to meet an objection to which we referred above; and we have introduced more organic chemistry of which, as some thought (*S.S.R.*, XVIII, 72, p. 595), there was little in the Minimum Syllabus.

7. THE EXTENDED SYLLABUS

It will be convenient now to describe the way in which we have compiled an Extended Syllabus. Our Minimum Syllabus, it will be remembered, was arranged to provide for schools, or parts of schools, where the allotment of time to Science was equal to 4 periods per week for 4 years, the periods being of 45 minutes each. So as to allow time for revision of past work and for testing the progress of the pupils, no special provision was made for "preparation" or homework and each of the three terms in every year was assumed to consist of only ten working weeks. That gave us a total of 480 periods, of which, in fact, we filled 453. In passing, let it here be said that we expressed no preference or otherwise for this particular apportionment of time, except to indicate (*T.G.S.*, p. 21) that we considered the total amount insufficient for an adequate survey of science. The work which we then scheduled can be fitted equally well into a course of five years by those who desire it. It did not occur to us that it was necessary to point this out, a fact which has given one of our critics (*S.S.R.*, XIX. 74, p. 302) the opportunity of saying that by publishing the Interim Report in the form used we have done a grave disservice to the cause of science teaching in this country!

Our original intention was to provide, in our final Report, for the many schools where twice as much time is given to Science in the pre-Certificate stage as in those for which our Minimum Syllabus was designed, that is to say, the equivalent of 8 periods a week for 4 years, the periods being of 45 minutes each. That would have given us a further 480 periods. Bearing in mind, however, that even in progres-

sive schools it is by no means uncommon to devote less than 8 periods a week during the first and second years, and realising that time must elapse before science masters in general will be able to acquire the faster *tempo* which we regard as ideal, we decided not to prescribe for a further 480 periods for Science in the more progressive schools, but to limit ourselves to 360.

There are many possible arrangements of the total time of 840 periods which we thus supposed to be available: 4-8-8-8 periods a week in successive years, or 4-4-4-8-8, or 2-4-6-8-8 and so on. Eventually, we decided to set out our work in a form suited to a four-year plan of 6-6-8-8 periods a week; but, lest we be charged with doing yet another disservice, let it be said on this occasion that the lay-out lends itself to intelligent adaptation by the simple process of drawing approximately horizontal lines across the syllabus according to individual preference. One further point with regard to the total allowance of time: the last term of the course is much broken by examinations and both teachers and pupils like to have time, especially towards the end, for general revision. We decided, therefore, not to fill more than 300 of the 360 additional periods to which we had limited ourselves.

In order to give flexibility and to provide opportunities for Schools to suit their work to their special circumstances and environment, especially in country schools, where the best laboratories of all lie outside the walls of the buildings, we have divided these 300 periods which are additional to those of our Minimum Syllabus into two parts; 200 for work which we consider could profitably be done by all and 100 for options. The full time which is available for the essential part of our Extended Syllabus is therefore $480 + 200 = 680$ periods. Of these, again being cautious, we have in fact filled but 655.

8. ESSENTIAL WORK: THE BROADSHEETS

In selecting the additional material for the essential part of the Extended Syllabus, we have used the same criteria as we did while composing the Minimum Syllabus, that is to say, we have kept in mind the interests and contacts of the pupils, choosing especially those through which important scientific principles may be taught. Much of the extra matter which we have now introduced we had previously considered but had reluctantly omitted for lack of time. None of the material has been inserted because it is physics or is chemistry or is biology; but we have again displayed it under such headings in the Broadsheets at the end of this book, simply because that is the easiest way of acquainting a reader with what is in our minds.

There are many ways in which the material we have chosen may be presented to the pupils: didactic; historical; heuristic; topical; practical; popular; intensive; by projects; by object lessons; by co-operative work and so on. The wise teacher does not slavishly follow any of these. The order of presentation may also be varied at discretion. In general, we have put first the things which quite young boys may be able to understand and have kept until later those which involve longer trains of logical reasoning.

We should like the syllabus to be read across as well as downwards, for we have tried to keep things which offer mutual support on or near the same horizontal level. If, as we hope, the same teacher will often teach all the subjects to the same boys, he may thus find it easy to zigzag his way through the syllabus, as suits his mentality and the circumstances of his school. Some of the most successful work of

which we know is done in that manner. Whatever methods of teaching are employed, we think that the items we have included in the essential part of our present syllabus are such as ought to be brought to the notice of all boys who are capable of appreciating them.

In order to study this part of our work in greater detail it will be convenient to compare it with the Minimum Syllabus of the Interim Report. On this occasion we have not displayed the teaching material lesson by lesson as we so often did before. To see the periods grouped together for any one topic may give the master who is interpreting the syllabus a greater sense of freedom to choose for himself the points on which to dwell. If he is in any doubt about the time which we think can best be spent over certain items, he may consult our previous recommendations. It will also be noticed that some topics have been elaborated in much greater detail than in others; in these the material may be novel or the method of presentation unorthodox.

We have been glad to have sufficient time at our disposal to introduce a little Astronomy and Geology, the more so as some of this work is suitable for the younger boys. The Astronomy is grouped within the physical part of the syllabus since the subjects are closely akin. Thus the physicists are invited to leave the laboratory for a time, in order to watch the forces with which they experiment operating on a majestic scale outside.

Part of the Geology which we have introduced into the essential portion of the extended syllabus is grouped with Chemistry and part with Biology, in order to make the affinities clear. It must be remembered that teachers of Geography often include a little Astronomy and Geology in their work, so that collaboration with them is most desirable. Further provision is made for Astronomy and Geology in the optional part of the syllabus, and it is hoped that ample use will be made of it.

Under Biology, in the second columns of the broadsheets,

there will now be found brief references to mosses and ferns; classification has been extended to include the lower animals; and a section on growth and regeneration has been added. Here and there throughout the syllabus, references to reproduction may be noticed and there is now a long section on reproduction in vertebrate animals. A still longer one on disease is based on Pasteur's work, an historic example of purposeful but simple experimenting. Mrs. R. L. Devonshire's translation of Vallery-Radot's *Life of Pasteur* (Constable, 7*s.* 6*d.*) would prove of great use to teachers who are new to this work.

The biological part of our syllabus has been designed to suit the abilities of boys approaching it at eleven years of age and to accord with their increasing grasp of chemical and physical ideas as they grow older. Another order of presentation is suggested on page 36 of the *Teaching of General Science*. This might be consulted by any who are in doubt about the lines of thought which run through the whole and these might be followed in places where, as in the Public Schools, boys do not usually begin any serious study of Biology until they have reached the age of fourteen years.

Under Chemistry, extensions will be found to the sections on metals and alloys; acids, bases and salts; and sulphur and nitrogen and their compounds. There are also considerable additions to the quantitative work required to establish the idea of constancy of proportions in compounds, especially with reference to the atomic theory. Silica and the silicates have received attention because of their importance in nature and in industry, and a brief reference has been made to phosphorus and a longer one to the chemical aspects of electrolysis.

A section on the sources and nature of fuels has been added to the Chemistry and there is also a brief one on food, a subject which will now be found mentioned in all three columns of the broadsheet for the third year of the course. Towards the end of the scheme there will be found a section on

organic chemistry, which is based, not on methane, though this is mentioned elsewhere, but upon the study of alcohol.

In Physics, the quantitative work has been increased by the introduction of coefficients of expansion, Snell's law, and the composition and resolution of velocities and forces. Centre of gravity and stability, the spectroscope, and a little about wave motion and pendulum motion now find places in the syllabus. The only other additions in this branch of the work are of the nature of extensions of sections which were already in the Minimum Syllabus, especially those dealing with changes of state ; and, as was said before, Physics and Astronomy have been made to support each other in the first columns of the broadsheets.

9. OPTIONAL WORK

It may be worth while to state once more that our intention in providing for a series of "options" to complete our syllabus is to afford opportunities for schools to suit their work to their special circumstances and environment, and to enable masters to develop their own interests or those of their boys. Our approach to this part of the work has been along the same lines as that to the Essential portion, i.e. the interests and contacts of pupils have been used as a basis for introducing important scientific principles and concepts.

Most of the suggested material is an enlargement of the Essential Syllabus and the greater portion of it has been arranged as a series of topics. Here also certain parts of the work are set out in greater detail than others on account of the more novel or less orthodox nature of the work. It must be emphasised that although these topics cover much of the possible ground they are not intended to be exhaustive. Many masters will doubtless develop alternatives on the same lines and with the same ends in view.

In the list of Options which is printed on the next page, the sections A to H have been arranged to occupy approximately 50 periods or half the time available for optional work. Sections J and K will require the full 100 periods.

Thus within the limits of our suggestions, the alternative choices are:

(I) Any two from A to H inclusive.

(II) Either J or K.

In certain of the sections, notably A, B, C and D, nearly

all the work is suitable only for the last two years of the course; if two of these sections are chosen it is obvious that there must be a rearrangement of the Essential part of the syllabus to leave sufficient time available at the end of the course.

The Options are as follows:

A. ELECTRICAL INDUSTRIES.

1. Generation and Distribution (3 periods).

Extension by about 3 periods, of "essential" work (Broadsheet, Year IV) on the following : D.C. Generator (field windings); A.C. Generator ; Transformers and Grid distribution.

2. Electrolysis (2 periods).

Extension, by about 2 periods, of the section "Electrolysis and Electroplating" in the Essential Syllabus (Broadsheet, Year II, Col. 1 and Year III, Col. 3), to include electro-chemical equivalent.

3. Electricity as a Source of Heat (3 periods).

Welding. The electric furnace employing the high temperature of the arc for (*a*) conversion of amorphous carbon to graphite, and also carborundum ; (*b*) manufacrure of calcium carbide for making acetylene (as a source of alcohol) ; (*c*) manufacture of phosphorus by reduction of calcium phosphate in a special furnace ; (*d*) fixation of nitrogen (Broadsheet, Year III, Col. 3).

4. Electricity as a Means of Ignition (5 periods).

The electric spark as a means of starting gaseous reactions (as in eudiometer experiments—see Option B) applied on a larger scale in the internal combustion engine. Induction coil ; magneto ; coil ignition on cars.

Meaning of ignition point. Nature of the action, as well as the source of energy, in the cylinder of a petrol engine.

5. Electric Discharge (2 periods).

Ozone formed from oxygen by absorption of energy. Recognition of ozone and simple facts concerning the allotrope of oxygen and its use for purifying air and water supplies.

6. Lighting (11 periods).

Illumination ; inverse square law ; simple photometry ; candle power and the foot-candle ; the lumen ; illumination desirable for various purposes.

Incandescent lamps : efficiency (watts per c.p.) of carbon fila-

ment, vacuum and gas-filled lamps. The spectra of incandescent lamps, comparison with that of Sun; the infra-red and ultra-violet portions (detection and utilisation); dependence of efficiency on temperature (opportunity here for brief discussion on degradation of energy).

The colours of objects in artificial light (Broadsheet, Year III); "daylight" lamps.

7. Discharge Lamps (4 periods).

The discharge of electricity through gases; less voltage needed to produce discharge at pressures lower than atmospheric. Characteristic colours; spectra of gases compared with those of incandescent lamps. (Refer to spectrum analysis in Broadsheet, Year III). Gas tube signs.

8. Traction (20 periods in all).

Motors (2 periods). (See Broadsheet, Year IV.)

Field windings; back E.M.F. and starting resistance.

Some mechanical considerations suggested by Traction:

Acceleration (14 periods). (See Broadsheet, Year IV.)

Time taken for a vehicle to gain speed. Performances of different vehicles in this respect. Acceleration in m.p.h. per sec. The more powerful the engine the greater the acceleration; the heavier the vehicle the less the acceleration. The slow acceleration of a steam train due to its great mass. The performances of certain trains. The final speed of a train may be very great. When resistances equal driving force, speed is constant.

Falling bodies: speed independent of mass, when influence of air is removed (mention of Galileo).

Acceleration of gravity: distances fallen during first five seconds.

Horizontal projection: idea of physical independence of forces.

Idea of central acceleration in uniform circular motion; banking of tracks.

Kinetic Energy and Speed (4 periods).

K.E. gained by W lb. falling through h feet is W.h. ft. lb.: since all bodies acquire the same speed, K.E. $\propto$ W.

(Speed acquired)^2 $\propto$ h (by experiment or calculation). Hence K.E. $\propto$ V^2.

Application to distance in which brakes can pull up a car running at different speeds.

B. THE NATURE OF MATTER.

Note: We are strongly of the opinion that the time has come when ideas of atomic structure, in a simple form, should be included in the teaching of elementary science. Suitably treated, such ideas make no greater demand on intellectual power than do some of the material which is traditionally associated with school science (e.g. the proofs of the formulæ of gases), whilst they are of intrinsic importance and have the advantage of appealing to interests already aroused by topical references.

1. Molecular and Atomic Theories (30 periods).

(Refer to Broadsheet, Year II, Col. 1, Diffusion, etc.)

Molecules as ultimate particles, differences in the "packing" of which correspond to solid, liquid and gaseous states. Wandering of molecules is more noticeable in gases: diffusion. Experiments demonstrating diffusion. Diffusion phenomena in everyday life.

Solution of gases in water and effect of pressure; aerated waters.

Similar behaviour of all gases towards changes of pressure and temperature (Broadsheet, Years II and III, Col. 1) suggests similar packing of molecules under the same conditions and leads to Avogadro's hypothesis. Some deductions from this: (*a*) comparison of weights of molecules from densities; (*b*) reactions between gases in simple volume proportions. Demonstration of gas reaction in which the reacting volumes are measured, e.g. hydrogen and chlorine; hydrogen and oxygen; or sulphur burning in oxygen.

Gas reactions such as that between hydrogen and chlorine suggest divisibility of the molecule. Dalton's idea of atoms. Certain laws of chemical combination follow from his suppositions and these allow of practical testing. The Law of Multiple Proportions.

The assumption that simple gases (hydrogen, oxygen, chlorine and nitrogen) contain two atoms in their molecules leads to the

gram-molecular volume. (Without going into detail it may be stated that there is evidence to support this assumption.)

Molecules in solids and solutions: crystal forms due to different arrangements of molecules in regular patterns. The properties of crystals are not limited to the obvious external characters but are shown by the nature of fracture and effect of light passing through them. Isomorphism.

Giant molecules in starch, silicic acid, etc., are unable to penetrate certain membranes. Properties of colloids and the colloidal state. Detection and precipitation of colloids. Reference to the importance of the colloidal state in living matter.

Reference back (see Option A, p. 30) to discharge of electricity through gases; low pressure phenomena; cathode rays, principal properties and historical importance. The identification of the electron; Millikan's work.

The modern idea of an atom as a "sphere of influence" rather than a solid sphere. Electrons and protons. The structure of a few simple atoms such as those of hydrogen, helium and sodium. How atoms combine by loss or gain of electrons. The number of electrons required by an atom to complete its outer ring decides its capacity to unite with other atoms. This is expressed by the *valency*, e.g. different numbers of chlorine atoms will unite with one atom of sodium, magnesium and aluminium. Valency represented by whole numbers between one and eight.

The nature of a radio-active element as one which is breaking down spontaneously. A few simple facts about radium and an indication of the possibility of changing one kind of atom into another.

2. A Chemical Family: the Halogens (20 periods).

Grouping of elements in families (cf. plants and animals, and hint at possible evolution of elements) with a glance at the Periodic Table of elements. The halogens as a family. Their general properties, peculiarities, and gradation in activity from fluorine to iodine, including replacement of one another (cf. metal replacement). Fluorine as a very active element; hydrofluoric acid and action on glass.

Occurrence of chlorine, bromine and iodine in sea salts. Selective absorption of iodine by sea-weeds (iodine and the thyroid gland). Iodine and iodoform in medicine.

Bromine from sea water: rise of a new industry. (Ethylene bromide in petrols.)

Chlorine from brine (see Option A on page 29, Option C on page 37 and Broadsheet, Year II, Col. 1 and Year III, Col. 3, under Electrolysis).

Solution of chlorine, bromine and iodine in water and organic solvents: the principle of extraction by one solvent from another.

Chlorine: uses and abuses; chlorine and hypochlorites for bleaching and antiseptics. Chloroform. Chlorine and phosgene as poison gases and how combated.

Potassium chlorate: study of its nature and uses; precautions for safety when using such powerful oxidising agents.

Reactions of silver nitrate with soluble halides.

C. CHEMICAL INDUSTRIES.

Note : Some important chemical principles are illustrated below from local industries which are to be found in certain areas. Agricultural contacts are not included as these are provided for elsewhere. A system of "local options" is suggested tentatively and this may be extended or modified according to the available facilities. The suggestions by no means cover all the possibilities; but the main idea is to employ the powerful stimulant of local contacts as a way of introducing important principles.

1. Light and Chemical Action: Photography (10 periods).

Chemical actions stimulated by light, such as the combination of hydrogen with chlorine. Chemical actions giving out light as the chief form of energy output; reference to any one good example of chemiluminescence (*S.S.R.*, XIX, 76, p. 489). Effect of light on silver salts: the basis of photographic processes. Silver bromide emulsion (gelatine as "protective colloid") and effect of light in forming a latent image which becomes metallic silver under the influence of reducing agents called "developers." Removal of unchanged halide by solution in "hypo" in "fixing." Toning a print: a replacement of silver by gold or platinum; replacement by a less electro-positive and more permanent metal.

The above illustrated by test-tube experiments showing the effect of precipitating silver bromide (with and without the presence of gelatine), action of pyrogallol and ferrous sulphate on a silver halide, etc. Home-made sensitive paper (by successive immersions in silver nitrate and sodium chloride solutions—with subsequent drying) used for silhouette prints. Solution of silver halides in concentrated solutions of "hypo."

Ferric ammonium citrate blue printing as another example of light action; "development" by double decomposition with potassium ferrocyanide.

The above may be used to demonstrate several general types of chemical action and some important principles: a photographic enthusiast might be inclined to extend them a little by the inclusion of a reference to panchromatic emulsions (see Broadsheet, Year III, Col. 1 and Option A, page 29), and the chemistry involved in the intensification and reduction of negatives (as further examples of oxidation and reduction).

2. Coal and Coal Gas (16 periods).

Note: Sections marked * are "local options", any one of which might be developed in greater detail according to the possibilities of illustration and introduction of essential principles. Ten extra periods may be allowed for this purpose.

The Lay-out of Gas Works.

The usual arrangements for the separation of coke, tar, sulphur, ammonia and coal gas.

Coal Gas.

Approximate composition of coal gas.

Methane: a simple hydrocarbon; its properties and combustion to carbon dioxide and water, typical of combustion of hydrocarbons in general; brief comparison with ethylene; occurrence as "natural gas"; relation, as simplest member of a family, to petroleum; reference to problem of obtaining oil from coal.

Nature of Coal Gas Flame.

Experiments demonstrating the structure of the bunsen flame and its oxidising and reducing regions. (Items in Broadsheet, Year III, Col. 3, are extended here.)

Coke.

(*a*) Use as a smokeless domestic fuel.

(*b*) A source of gaseous fuels: (i) with air to give producer gas, and (ii) with steam to give water-gas. Admixture with coal gas in domestic supply. Properties of carbon monoxide. Determination of carbon monoxide in coal gas, and carbon dioxide and monoxide in the product of heating charcoal in oxygen, as examples of gas analysis.

* (*c*) A reducing agent in iron smelting. Working of the blast furnace. Manufacture and use of steels; special steels.

(*d*) A source of synthetic materials of industrial importance:

(i) Through water-gas by catalytic treatment with hydrogen to give methyl alcohol. Catalytic oxidation of this to formaldehyde. Treatment of formaldehyde with phenol to give a plastic (bakélite).

* (ii) Manufacture of calcium carbide. Acetylene. Industrial synthesis of acetaldehyde from acetylene. Indication of the importance thereof in providing a source of alcohol independently of plant material. (See also Option A, page 29.)

* *Coal Tar.*

Isolation, by distillation, of benzene, toluene and phenol. Benzene through nitrobenzene to aniline as an example of initial stages of chemical treatment of benzene leading to useful coal-tar products. Preparation of a simple dyestuff.

* *Coal and Fertilisers.*

Ammonium sulphate. Its manufacture a self-contained process in a gas works or coke-oven plant, involving production of sulphuric acid from recovered sulphur. Catalytic oxidation of recovered ammonia supplies oxides of nitrogen for the chamber process.

Basic slag from steel manufacture. Calcium cyanamide from calcium carbide. Estimation of ammonia in a commercial fertiliser. (See also Options H and J.)

* *Sulphuric Acid.*

Production of sulphur dioxide from sulphur or sulphides (pyrites and gas works product) and conversion to sulphuric acid by (*a*) contact process (diversion on catalysis and reversible actions); and (*b*) chamber process: oxides of nitrogen as oxygen carriers, concentration of acid and other problems presented. (Either process, according to local possibilities of illustration, will provide opportunities for introduction of such matters as rapid determination of "strength" of acid from hydrometer reading; action of concentrated acid on materials possible for containers, etc.)

Reactions of sulphuric acid which form the basis of large-scale uses e.g. iron pickling, ammonium sulphate, nitric and hydrochloric acids, accumulators, etc.

Uses of the acid in the laboratory. Sulphuric acid as a strong, but not the strongest acid.

3. THE ALKALI INDUSTRY. COMMON SALT AS A SOURCE OF SODIUM COMPOUNDS (14 periods).

Extraction of salt by mining and evaporation of brine. Purification of substances by recrystallisation. Preparation of pure sodium chloride from common salt; the "common ion" effect; brief reference to mass action.

Outline of the conversion of salt into sodium carbonates by the Solvay process. Conversion of one carbonate into the other and their main uses. Lime and carbon dioxide from limestone. Ammonia from ammonium salts.

Caustic soda from washing soda by (*a*) treatment with lime (reversible action), and (*b*) from salt by electrolysis. Metallic sodium from caustic soda. (See Option A on page 29, Option B on page 33 and Broadsheet, Year II, Col. 1 and Year III, Col. 3.)

Alkalis in general. Plant ashes as original sources of potash. Potassium compounds in the soil; their sources and importance.

Sodium sulphates from common salt. The idea of basicity of acids.

D. WAVES (INCLUDING WIRELESS).

1. Revision of Elementary Ideas of Waves (5 periods).

Distinction between movement of wave and movement of medium. Vibrations: spring and pendulum as types; time of oscillation independent of amplitude; diagram, model or film to show that a line of particles executing S.H.M. with constant phase difference between adjacent particles gives impression of disturbance moving along; meaning of wave-length; velocity of wave; $V = n\lambda$. Similarly for longitudinal waves.

2. Sound Waves (7 periods).

Stationary waves: nodes and anti-nodes. Demonstrations by means of strings and Kundt's tube. Overtones in wind and string instruments. Timbre. Beats. Mechanical and electrical reproduction of sound; effect of varying response; distortion. Doppler's principle (qualitatively).

3. Light Waves (3 periods).

The spectrum; infra-red and ultra-violet. Scattering; blue sky and red sunset. Infra-red photography.

4. Wireless Waves (31 periods, in all).

Preliminary electrostatics (9 periods).

Electrification; charging by friction; like and unlike charges; definition of positive and negative; conductors and insulators; charging by contact; testing sign.

Induction; electronic hypothesis; identification of positive and negative charges separated by induction; charging leaf electroscope by induction.

Distribution of charge: no charge inside conductors; variation of density with curvature; action of points; lightning conductors; leaf electroscope as voltmeter.

Condensers: factors governing voltage of charged conductors studied by electroscope; capacity; types of condenser; the

condensing electroscope used to indicate pressure from cells and mains.

Note: The aim of the above work on electrostatics is the understanding of the condenser. The treatment shows the orthodox or traditional method of approach. It is, however, possible to develop the same ideas by extending the work on current electricity, e.g. by demonstrating the momentary current on charging and discharging a 2 M.F. condenser with a 200-volt H.T. battery using a Neon lamp as a detector.

Brief Survey of Early History of Wireless (11 periods).

Experiments of Hertz and outline of conclusions. Marconi's contribution of aerial and earth.

Construction of simple spark transmitter (*S.M.B.*, Series 1, Part 1, p. 224). Rectification by crystal. Construction of simple receiving circuit and reception of spark.

Resonance; demonstration (e.g., tuning fork over water; refer to other manifestations); tuning of receiving circuit.

The Valve (11 periods).

Discharge tube and change in character of discharge as pressure is further reduced; cathode rays; electron. Valve action of diode (use triode without grid): change of plate current with variation of plate voltage plotted.

Action of third electrode; static characteristics determined practically.

Amplification and rectification. Reaction and continuous oscillation; construction of simple valve oscillator; possibility of speech transmission by modulation of continuous wave.

E. FURTHER GEOLOGY AND ASTRONOMY.

1. Geology (35 periods).

Note : The co-operation of Natural History Societies with work in this subject, much of which must of necessity be done in out-of-school hours, is most important. Interest may be maintained by offering prizes for geological work done voluntarily during the holidays. Geological maps of the districts which are visited may be drawn ; sketches may be made of quarries and other sections which are seen ; descriptions of the observed geology may be written ; and collections of rocks, minerals and fossils may be made. The boy in a rural school can see rocks in quarries and can observe the outlines of the country and the courses of the streams ; the boy in an urban school may observe many different rocks used as building stones and for roads in his town. From the very start, boys should be encouraged to record observations bearing on the subjects discussed and to make drawings of the things they see. Simple maps should be compiled and duplicated, so that each boy may have copies. Throughout this suggested course observation should be linked with practice, the connexion between every-day life and science being kept in view. Most of the work is suitable for the first two years of a course in general science, if the teaching is kept on an elementary plane. Attention is called to a note on page 78 and to the Broadsheets.

The changing Earth. Surface alterations on Nature's surfaces and on artificial ones, e.g. paths and country roads. Running water as agent of erosion and transportation. Frost and its splitting action. Accumulation of waste (screes) at foot of walls, quarry faces and hillsides.

Hard and soft rocks (related to the above). Simple discussion of land forms showing differential weathering. Weathering of old walls. Dressed stones develop natural grain.

Common rocks of neighbourhood (observed characters and differences). Rocks (stones) brought into the district for buildings or roads, compared with local ones.

The make-up of common rocks: a conglomerate, a sandstone, a shale or clay, a limestone. Examination of these rocks, using lens and acid, both before and after breaking them up. Comparison with loose pebbles, sand, mud and broken shells.

The making of common sedimentary rocks: (*a*) raw materials in Nature and how they are obtained (see above); (*b*) hardening processes: pressure; cementing. Refer to artificial stones, e.g. concrete, brick.

The work of the sea: coast features; sorting arrangement (stratification); intermingling of organic remains.

Earth movements: raised beaches; submerged forests; sea-shells in rocks above sea-level; tilting of beds; dip.

Solvent action of water: solution and precipitation. (*a*) Solution of limestone in water and carbon dioxide. Scenery of a limestone country. Caves. (*b*) Precipitation of caltium carbonate in water-pipes, kettles and caves. Preserving action of the deposit.

Internal heat of earth (simple evidences): rise of temperature in mines; hot springs; lavas; crystals formed by cooling molten solid. Crystalline rocks: Granite. Obsidian (cf. artificial glass).

Observation of rocks in the neighbourhood, in quarries or roads or buildings.

How to record observations on a map. Strike and dip. Outcrop. Width of outcrop related to thickness and dip. Drawing of simple sections.

The work of rivers: springs; erosion and transport; valley formation; waterfalls; meanders; rejuvenation; gravels; terraces; deposition in lakes; silting; alluvium; deposition in sea; estuarine deposit; deltas.

Study of a map of a district dissected by river action. Dip and strike valleys. Escarpments. Outliers. Section drawing through a scarp and an outlier.

Glaciers: work of erosion and deposition; evidences of glaciation in areas now free from ice.

Further study of igneous rocks: a volcano and its products. Ashes and breccias. Lavas—(*a*) Fine types: glasses. (*b*) Coarse types: included crystals and what they indicate. Non-extrusive types: dyke rocks; Plutonic rocks.

Earth structures and movements: folding and faulting; synclines and anticlines; compression and tension; jointing.

Map study and section drawing of synclines and anticlines. Their relation to forms of outcrop.

Common types of fossils. Living representatives of fossil forms.

Common minerals of the earth's crust and their recognition: quartz; felspar; mica; hornblende; calcite.

Mineral veins and ore deposits. Recognition of iron pyrites, copper pyrites, malachite, galena, hæmatite. Elementary ideas about mining. Extraction of iron from hæmatite and of lime from lime stone.

Stratigraphy. Superposition. Broad divisions of geological formations: Primary, Secondary, Tertiary, Recent.

Cycles of denudation. Cycles of deposition. Unconformities and their significance.

Man's ancestry and prehistory: Palæolithic man: his remains; weapons and tools in cave deposits and gravels.

Neolithic man: his remains; weapons and tools; and burial mounds.

Bronze Age man: his structure; flint and bronze weapons and tools; his burial mounds and pottery.

Early Iron Age man: his structure; weapons; tools; camps and pit-dwellings.

Economic Geology of to-day: peat; coal; oil.

2. ASTRONOMY (15 periods).

Note: As relatively few schools have facilities for the specialised teaching of Astronomy, and as instruments are not likely to be readily available in after life, chief emphasis is here laid on phenomena which may be observed with the unaided eye. The use of a planisphere should be encouraged and attention should be drawn to astronomical references in the daily press, especially to articles such as *Stars of the Month*,

which appear periodically in *The Times* and other papers. All the topical information which the teacher requires is to be found in *Whitaker's Almanac*. Perhaps the chief object of a short course of this sort is to arouse a feeling of wonder and to stimulate an interest which may provide lifelong pleasure. Attention is drawn to a note on page 78.

Recognition of Cygnus; Vega; Pegasus; Andromeda; Perseus; Cassiopeia; Pleiades; Aldebaran; Orion; Betelgeuze and Rigel; Castor and Pollux; Sirius; Procyon; Capella; Leo; Regulus; Milky Way. (See Broadsheet, Year I.)

Right ascension and declination in relation to a star map.

Altitude of Pole in relation to latitude (quite roughly; no corrections).

Nebulæ: The nebulæ in Andromeda and Orion; Milky Way as a spiral nebula seen from within. Modern ideas of the constitution of the Universe and the birth of stars. The light-year as a unit of time.

The stability of the Solar System: elliptical orbits; Kepler's first two laws; Newton's first two laws, central force and gravity; any disturbance of equilibrium would be followed by readjustment. (See Broadsheet, Year IV.)

The histories of the discoveries of Uranus, Neptune and Pluto.

Spectra of Sun and stars in relation to their constitution; the discovery of helium. (See Broadsheet, Year III and Option A, p. 30.)

Speculations on the birth of the Solar System. It is unlikely that there are many such systems.

Measurement of time: solar time compared with stellar time; sun-dial (very simply); Greenwich Mean time; Summer time.

F. FURTHER BIOLOGY.

The optional work in Biology, which is estimated to require about fifty school periods, is divided into four parts: (1) observational work done chiefly out-of-doors, (2) a course on the supremacy of man amongst the animals, (3) a course on heredity, and (4) a course on behaviour.

1. Observational Work (12 periods).

This is intended as an extension of the work printed in Year II of the Broadsheets under the title of "The Web of Life" and described more fully on page 45 of *The Teaching of General Science;* but whereas the observations then proposed were of a general kind, those now suggested are more specialised.

One definite group of the animal kingdom (e.g. birds, or mammals or fish or butterflies or spiders, etc.) might be chosen for prolonged study. Properly documented records should then be kept, with as much relevant data as possible, and an attempt should be made to compile year by year a natural history of the region surrounding the school. If collections of specimens are made at the same time, they may develop into a local museum.

As alternative suggestions, a study of the common trees might be undertaken, their characteristics and their changes with the changing seasons; or the use of a *Flora*, for the purpose of keeping a record of the plants of the locality, might be taught. The Le Play Society, of 1 Gordon Square, W.C.1., has recently published a Regional Survey Field Service Pocket Book under the title of *Exploration*, which directs attention to a great number of possible fields of local exploration. It costs but fourpence, with an extra penny for postage.

Simple experimenting in observational work is often well within the powers of boys; on such matters, for example, as the relationship between insect population and temperature and humidity The possibilities are, indeed, limitless; but the main

idea here should be to get boys to learn from nature rather than from books and to collaborate in making the records of their observations available for their successors.

Even in large towns, ingenuity may reveal unexpected opportunities of the kind we have in mind; but if conditions are really hopeless, there may be a botanical or zoological garden or a natural history museum to provide suitable alternatives.

2. THE SUPREMACY OF MAN (18 periods).

Note: Although some of the matter compiled in this topic must be taken towards the end of the whole course, about half of it can be used quite early; and the earlier the better, if the pupils are to be led to consider biological principles in relation to their own lives.

Man (Homo sapiens) constitutes a family (Hominidæ) of one order (Primates) of the Mammals.

Differences in structure between man and the other animals: size of brain in relation to that of body; shape of skull; long big toe (prehensile feet of babies); erect posture; fore-limbs, especially hands, of exceptional mobility.

Differences in behaviour (see also Behaviour below): reason, i.e. dealing with concepts, as transcending animal intelligence; language, oral and graphical; moral conduct, i.e. control of actions by reference to ideals; self-criticism; religion ("the praying animal"); the social heritage; thinking in relation to (past, present and future) time.

Speculations on primitive movements towards civilisation: e.g. the use and making of tools; clothing; husbandry; domestication of animals; fire; cooking; pottery; communal life, differentiation of labour, society.

Control of environment: the gradual eradication of harmful animals; the breeding of new types of animals and plants; the biological control of pests; brief mention of feats of civil engineering.

Some of man's achievements: Stone-throwing; sling; javelin; bow-and-arrow; gun. Smoke signals; carrier pigeon; telegraph; telephone; wireless. Log-riding; canoe; row-boat; sailing-ship; steamship. Sledge; roller; wheel; wheeled

vehicles; motor-car. Balloon; aeroplane. The submarine. Artificial light. Successes in the war against disease. (See Broadsheet, Year III.)

Achievements in the field of pure research: Science was born when man first began to notice orderliness in natural events. He was assisted by capacity for thinking quantitatively and by ability to make tools and instruments: e.g. cubit, foot, metre, micrometer; bushel, pound, gram, steelyard, chemical balance; microscope, telescope, spectroscope, X-rays.

The Quest for Power: use of animals; water-wheels; windmills; steam-engines; turbines; internal-combustion engines; power-operated tools; electric transmission; fuels.

Some of Man's Mistakes: the introduction of rabbits into Australia, sparrows into U.S.A., musk-rats into Europe, and grey squirrels into England. The excessive shooting of birds of prey is harmful to agriculture. Other biological crimes committed in the name of sport.

Some Thoughts for the Future: Man has not yet made any systematic attempt to apply scientific knowledge to problems related to his own posterity; and he seems unable to safeguard his social heritage against the effects of individual and sectional and national greed. In a superabundant world there are famine and strife: Why?

3. HEREDITY (8 periods).

Heredity and Environment in relation to the organism—not for exhaustive treatment, but by way of introducing the topic.

Some evidence for and against the transmission of acquired characters.

The struggle for existence and the survival of the fittest.

The germ-plasm theory (gonad and soma).

Continuous and sudden change. Examples of mutation.

Mendel's work, very briefly described.

The "mechanics" of growth and reproduction, illustrated by microscope and lantern slides, e.g.: a protozoon conjugating and dividing; normal cell division (mitosis), e.g. tip of onion root; testis, e.g. of frog, with cells in various stages of development; ovary, e.g. of fowl, ditto; spermatazoa, various; fertilisation of frog's ovum; revision of early stages in development of

frog; various stages in development of chick; parallelism in development of vertebrate embryos; theory of recapitulation of evolution; diagram of formation of egg-cell (meiosis) and of formation of male cell; illustrations of Mendelian segregation.

The gene as the possible physical counterpart of a transmissible characteristic. Caution about accepting conclusions as wholly true or the whole truth.

Practical applications in the breeding of plants and animals. Possible applications to man.

4. Behaviour (12 periods).

The outlines of a course on Behaviour are included, since many teachers like to direct their pupils' attention to their own modes of behaviour in comparison with those of the organisms which they are studying. Some go further and say that therein lies the chief justification for the teaching of Biology.

The course outlined below is an optional one, when considered as a whole; but, in any case, many points of behaviour will be mentioned, while dealing with the various organisms which are included in the syllabus, for the pupils' interest in such matters is very great. It would be well to deal thus with the points mentioned below, so far as may be done, leaving the residue to be added at a time when it is convenient, for purposes of revision, to collate thoughts about Behaviour. It might prove tedious to teach this special subject consecutively for the twelve school periods, which it is estimated to require.

The schedule which is printed below, is in the nature of an analysis. In teaching, it would be undesirable to follow the lines too closely. A better approach would be to start, for example, with a general comparison of the behaviour of (*a*) a radio receiving-set, (*b*) a plant, (*c*) a dog, (*d*) a man; and to point out that (*a*) reacts to radio waves, (*b*) to sunshine, (*c*) to the smell of meat and (*d*) to what he reads in the paper. For the pupil the analysis should come last.

Differentiation of structure and function, illustrated especially by amœba, paramecium, hydra and earthworm.

The cell in a higher animal has its individual life besides contributing to that of the organism of which it is a part, e.g. the white corpuscles in human blood.

The communal life of insects (e.g. ant or bee) compared with the less strictly communal life of man.

Instinctive and intelligent behaviour. Unlearned reactions: direct responses of protoplasm; reflexes; instincts. Conditioned reflexes. Variation of instinctive behaviour by experience: trial and error; reasoning. Increased variety of response in higher animals.

Man's physical form in relation to his intelligence. The manifestation of intelligence in the control of the forces of nature. Man's contemplative habit of mind and his idealism.

Habits, acquired usually by conscious efforts. Kinds of habits: motor; thinking; feeling; physiological (drugs, etc.). The importance of building up good habits, for on these character rests.

Sensations (localised) and *emotions* (general). Emotions of various kinds, but with the general qualities of joy and sorrow. Ductless glands, in relation to emotions. The expression, effects and training of emotions.

Mental adaptation: the importance of estimating one's limitations and potentialities and directing oneself accordingly.

G. ECOLOGY

The following suggestions for studies in Ecology are made on the assumption that the subject will be adopted as a half-option in some schools. To do the work adequately, but not to overdo it, would require about 50 extra periods, apart from time which is saved by duplication of parts of the Essential Syllabus.

Ecology is primarily a field study, but much of the biological work done in school may be based on observations made and material collected during the field work. Since the opportunities for this vary considerably throughout the schools of the country, it is impossible to define a syllabus which would be suitable for all; the following suggestions should therefore be regarded only as indicating a possible method of procedure.

In the earlier work it would probably be best to select a community in which the various associations are fairly clearly defined and in which the number of species is not too great. Examples may be found in salt marsh, sand-dune, heath or heather moor, waste ground in process of cultivation, open common land, aquatic vegetation, pine wood, etc. More complex communities, such as other woodlands, might be left for later study. In cities, although the conditions are as a rule artificial, home and school gardens, streets, parks, river banks, waste building ground, rubbish dumps, the home, etc., show characteristic flora and fauna.

A general survey of the ground will show the size of the area to be considered; thus, in studying salt marsh, it would be necessary to examine an area including the ground washed by the highest tides; a line transect taken at right angles

to the shore-line through this would show the zonation; one or more quadrats (one square metre) would then be taken in each of the zones, on both sides of, and not more than a few yards from the transect line. Hedgerows provide examples in which a variety of conditions is found within a small area. On the other hand, in such communities as mixed woodland and scrub, a much larger area must be studied. An excellent brief account of such work done by a school on some 25–30 acres of Ryhope Dene is to be found in the *School Science Review*, Vol. I, No. 4, page 113, under the title of "Local Ecology as a Basis of School Botany," by E. Price Evans.

All records taken in the field should be carefully dated and filed in order that examples of colonisation and succession may be studied. Such records should include photographs.

The area under consideration should be mapped.

The species present should be identified and listed.

Any special points of morphology should be noted.

The various associations plant and animal (if possible) in the area should be determined:

(*a*) use of list or chart quadrat or both (see note below);

(*b*) use of transect.

The ecological factors should be analysed:

(*a*) Physiographic: general topography; altitude; slope of the land; drainage conditions; mobility of the soil.

(*b*) Climatic: temperature; rainfall; wind; light intensity and duration; evaporating power of the air; seasonal variation.

(*c*) Edaphic: soil texture and simple analysis; water content; organic content; acidity or alkalinity of soil.

(*d*) Biotic: competition; pollination and dispersal mechanisms; parasitism: symbiosis; fungi and bacteria; influence of microscopic animals, earthworms, and other soil dwellers, of herbivorous animals and birds, of man; origin of colonists.

(*e*) Special features: smoke; influence of paths, roads, railways, fires, etc; mowing and agricultural activities.

Notes: The same type of community, and other types of

communities should be visited in other areas for purposes of comparison and contrast.

Where opportunities occur, experiments of the type involving artificial drainage, fencing, etc., should be included.

The normal size of the quadrat is one square metre, but this will depend on the type of vegetation: if woodland or scrub, it might be necessary to take 5 or 10 metres square, and in a mature forest of larger trees 100 square metres might not be enough.

Colonisation experiments can be carried out on areas as small as one square metre; by digging out the earth in such a square to a depth of one and a half feet to two feet and introducing different kinds of soil and subsoil it is possible to extend the range of such experiments.

It is desirable to link up field work in Ecology with that in Geology.

H. and J. GARDENING.

In schools where facilities exist, the pursuit of gardening offers a good introduction to, and serves to enlarge, the scope of the study of Biology. Accordingly, we submit below suggestions which may be useful for this purpose. It is desirable that the gardening should be real gardening and not only applied science. For this reason, æsthetic and utilitarian values should not be neglected, and boys should be encouraged to take a pride in the horticultural amenities of their school. We should like, however, to make it quite clear that these suggestions are not being put forward as a study of technical gardening, but as the basis of biological work in classroom and laboratory. The master, therefore, bearing in mind the underlying principles involved, should prepare a scheme of indoor work to suit the activities which go on outside in much the same way as is shown later in the case of Agriculture (see pages 56 *et seq.*).

It is a mistake to think that residence in the country is necessary for pursuits of this sort. Those who wish to gather ideas of the possibilities of training through gardening may get help from the Board of Education's Educational Pamphlet, No. 41 (H.M. Stationery Office, 1922, 2*s*.), which describes the work which was done in Botany under the direction of the late Dr. Lilian J. Clarke in the gardens of the James Allen's Girls' School at Dulwich. It would be better still to consult Dr. Lilian Clarke's own book, *Botany as an Experimental Science*, which the Oxford University Press published at six shillings in 1935, for in this it is shown how the work in the gardens may be linked with that of the laboratory. The Ministry of Agriculture also supplies numerous pamphlets which teachers would find of great assistance.

The scheme set out below should count as a full Option, for it would need about 100 periods in addition to those saved by duplication of parts of the Essential Syllabus. There may be many, however, who are unable to take so full a course, though wishing to do something of the kind. To them we suggest that they might make a half-option of the course by omitting the parts about fruit culture, and some of the more specialised work. Less ground as well as less time would then be required. A restricted course of this sort would fit into position H in the scheme printed on page 28.

Even in schools which have no space at all for gardening it would be found that boys are glad of encouragement, by the distribution of seeds and so on, to carry out work in their own gardens at home. Their records of the growth and characteristics of the plants can be made both interesting and valuable. Flower gardening, as Mr. H. R. V. Ball has pointed out (*S.S.R.*, XVII, 68, p. 568), is one of the commonest adult hobbies and his enquiries led him to believe that the majority of children in semi-suburban districts do regular work in their gardens and that many spend a great deal of their time in them.

Use of Garden Tools: digging, double digging, winter and spring digging; soil and subsoil; making a tilth; preparing a seed bed.

Sowing or planting seeds of a few common vegetables, e.g. (1) Potatoes, (2) Peas and Beans, (3) Carrots or Parsnips, to give ideas of a simple rotation. Reasons for rotation.

Sowing of seeds in boxes; use of cold frame; transplanting. Further care of crops: hoeing, thinning, etc.

Uses of manures: farmyard, green, and artificial.

Flowers: annual, biennial and perennial. Propagation of herbaceous plants; cuttings (e.g. Pinks, Carnations, Chrysanthemums); layering (e.g. Carnations); division (e.g. Iris).

Budding, with special reference to rose culture.

Planting and care of a small herbaceous border: planning; arrangement of species; consideration of size, colour, time of flowering. Bedding out plants. Potting and planting of bulbs.

Fruit culture: outline of methods for growing Apples and bush fruits; pruning and grafting of Apples, use of East Malling stocks. Nursery stages and bush formation in black and red Currant.

Laying out a small garden: principles to be observed; use and abuse of formal features; combining utilitarian and æsthetic aspects.

Soils: mechanical analysis; humus content; recognition of various types of soils; action of water and frost; effects of rolling, hoeing, mulching.

Germination: experiments to show conditions necessary for germination; methods of meeting these in the garden.

The growing plant: simple structure of root, stem and leaf (lens and microprojector); simple experiments to show functions and relations of various parts; intake of raw materials, manufacture and transference of food stuffs to seeds, stem or roots; reference to annuals, biennials and perennials.

Further study of soils: simple tests for plant foods in soil; formation of acid; effects of liming; determination of lime requirement. Short study of manures: farmyard, green and artificials; functions of nitrogen, phosphates and potash; water-culture experiments. Flora and fauna of soil, illustrated by a few water-culture experiments; partial sterilisation.

Propagation: how plants propagate themselves and how the gardener uses their methods; the distribution and functions of cambium and its importance in practical gardening.

Further study of movements of substances in plants with special reference to pruning, ringing and root pruning.

Plant breeding: a few crossing experiments with two pure lines of Peas to illustrate Mendel's Law.

Garden pests: study of commoner "insect" and fungoid pests of the garden; treatment and prevention.

K. AGRICULTURE.

In schools which are situated in rural districts, full advantage should be taken of the exceptional opportunities for connecting the work of the lecture-room and the laboratory with that of the world outside. So far as is possible, the scientific work which is done in such schools should appear to arise from problems which are met with in the fields or the gardens outside. This way of presentation is most important, in order to maintain the interests of the boys and to supply that "close to the soil wisdom" which should be one of the attributes of rural studies.

As instances of the kind of work which is possible in this connexion, two courses are given below in considerable detail, one relating to a pasture field and the other to arable land. In either case, a considerable portion, perhaps one-third, of the school time required for the course should be used in outdoor practical work. This should be undertaken by groups of boys working in close co-operation with other groups which are engaged on kindred tasks, for several different investigations may run concurrently. The remaining portion of the time, which is occupied indoors, should be devoted to working through a plan of study designed to suit the work which goes on outside. An example of such a plan, suitable to some of the practical work which is suggested later, is printed below.

It will be seen that the plan covers a considerable amount of the work which is scheduled in the Broadsheet. When allowance is made for this, it is estimated that 100 extra school periods should be amply sufficient for the full course, which provides a valuable Option for schools which are favourably situated for enterprises of this sort. Where country schools

are unable to venture on such full schemes as those which are suggested below, it is to be hoped that something less elaborate but on similar lines may be done, so as to add worth and reality to the studies of the class-room.

Pasture Land

PLAN OF STUDY

(i) *The Plant as a whole.* Examination of a few typical plants as a whole, in situ and after careful removal from the soil, e.g. a grass, clover, thistle or dandelion.

(ii) *The Shoot System.* (*a*) Further examination of the shoot systems of a number of representative species: erect shoots, stolons, runners, etc. Methods of growth, of vegetative reproduction and of storage.

(*b*) The Stem. The general scheme of structure as seen by naked eye, lens, microscope and microprojector. Relation to function should be indicated, but details of structure need not be memorised.

(*c*) The Leaf. Examination of the leaves of a number of representative species. Microscopic leaf structure should be shown and the relations to functions indicated. The cell as a unit of life should be emphasised.

(*d*) The Flower. Examination of a few representative species. The arrangement of only one flower need be memorised and only a few technical terms should be used.

(*e*) Pollination and Fertilisation. Examination of the stamens and pollen grains and of the styles and stigmata in a few species. Observation of the growth of pollen tubes in a culture medium. Artificial pollination (e.g. of Buttercup) should be performed by removing the stamens before dehiscence; syringing with water; placing a *fine* muslin bag over the flower; dusting with pollen from another flower; and replacing the bag. The agency of wind and insects should be considered briefly and self-pollination and cross-pollination should be investigated experimentally.

(*f*) Seed and Fruit. Examination in a few representative species; morphology should not be stressed and only a few technical terms should be used. Special methods of seed dis-

persal should be noticed but not over emphasised. The dispersal of the seeds of a few common plants which have no special methods should be considered.

(iii) *The Root System.* Further examination of the root systems of a number of representative species. Measurements of a few systems. Observation of growth (holes, trenches, window-pane observations). Comparison of the growth of root systems of the same species in different kinds of soil.

(iv) *The Principal Plant Species of the Pasture.* Their identification; the definition of a weed. Determination of the botanical composition of the sward and description in terms of good grasses, weed grasses, legumes, and herbs and miscellaneous weeds (according to the Jones/Thomas Method (see *Agricultural Progress*, Vol. X, 1923).

(v) *Simple Physiology of the Plant.* Here it may be necessary to use plants other than those typical of the pasture.

(*a*) The chemical composition of plants; simple experiments to demonstrate moisture, carbon, nitrogen and ash content.

(*b*) Nutrition. The use of culture solutions. Nitrogen fixing bacteria; simple demonstration of these organisms and their work.

(*c*) Photosynthesis. The necessity for light, chlorophyll and carbon dioxide; the formation of starch and oxygen.

(*d*) Respiration. Intake of oxygen; output of carbon dioxide; loss of dry weight by seedlings in early stage; heat production.

(*e*) Demonstration of water uptake and of water loss.

(*f*) Food reserves: their nature; simple tests.

(*g*) Enzymes.

(*h*) Germination of seeds of species typical of the pasture, as well as of usual types of germination.

Note: The fundamental importance of plant life to man should be emphasized and discussed, e.g. the part played by nitrogen-fixing bacteria; the importance of photosynthesis as the world's greatest method of storing up energy, by forming food material and making oxygen; the importance of respiration as a method of liberating energy and its relationship with combustion.

The influence of absorption and transpiration on crop production and the main principles underlying a simple crop rotation should be mentioned.

(vi) *Soil and Sub-soil:* Nature and composition of soil and sub-soil. Taking of soil samples. Determination of moisture content, humus, carbonate, "sand." Demonstration of the more important physical properties, air content, drainage, capillarity.

(vii) *Micro-biological Content of the Soil:* Culture of soil protozoa in sterile hay infusion. Demonstration under a microscope or with microprojector.

(viii) *Insects:* The study of a few life histories should be made as occasion provides. The main points for consideration should be structure, life history and the treatment of pests. The life histories of insects should not be memorized, but proper care should be taken to instruct boys how to make use of a text-book of reference.

Examples of insect study:

Sheep Maggot Fly: The flies can be trapped by means of a square box with a wool bait and a glass circular jar. Various stages can then be observed.

Ox Warble Fly: The larvæ can be squeezed out from the hides of cattle in April and May. Incubation can be effected in a jam jar at about 55 to 60 degrees Fahrenheit.

Click Beetle and Wire Worm: The wire-worm can be captured in potatoes and a study can be made.

Cinnabar Moth: This and other insects can be suitably studied (in situ) or in a corner of the School gardens on their host plants covered with muslin. The use of the Cinnabar moth for eliminating ragwort from pastures in Australia might be mentioned.

Aphides and Ladybirds.

(ix) *Worms:* Life history and general structure in relation to mode of life. Importance in aeration of soil and humus intake.

(x) *Birds:* Anatomy of the fowl by dissection. Observation of early stages of embryo by suspension in warm salt water. The main principles of the feeding of the fowl.

(xi) *The Mole:* General structure; mode of living; the Mole as a pest.

The Rabbit: Anatomy by dissection (the Pig or the Sheep may be substituted); its mode of living; the Rabbit as a pest.

OUT-DOOR PRACTICAL WORK.

The scheme should include one or more large-scale, worth-while pieces of work carried out co-operatively by groups of boys. The importance of such work will be realized when it is remembered that the problems that Nature presents are usually complex and seldom capable of solution by any simple test. If a boy leaves school with his idea of work limited to that which has been conceived and performed on the small scale, he may be timid in experimenting boldly on a broader basis later on, and limited conception prevents the interweaving of knowledge gained at school with social duties in after life.

The following pieces of work are examples of what may be done:

The incubation of chicks by natural and artificial methods.

Poultry keeping by various methods.

The effect of poultry folding units on the botanical composition of a pasture.

The comparative effect of high protein and low protein rations on growth, feathering capacity, maturity, egg-laying capacity, fertility and hatchability.

Observations upon the habits of wild birds that frequent pasture land, by trapping, ringing and release of birds with records of migration.

The effect of grazing by wild rabbits upon the botanical composition of a pasture.

Comparison between pasture fields in different districts.

The geology of the district and its relation to crop distribution, and the distribution of the natural flora.

The effect of pig folding units on the botanical composition of a pasture.

The effect of grazing with dairy cows upon the botanical composition of a pasture. (Relatively simple and practicable on the small scale with the assistance of an interested farmer.)

The effect of manuring upon the botanical composition of a poor pasture.

Some notes to indicate the cost and scale of the foregoing pieces of work may be of value. The experiments with poultry are fairly simple to carry out and, under competent supervision, they can be done by beginners and may be commercially profitable. The one dealing with the effects of rations requires 60 pullets and six plots, each approximately 7 yards by 15 yards in area.

Experiments connected with the effect of grazing by dairy cattle on the botanical composition of a pasture need not cost anything more than the value of the posts and wire required for dividing off small experimental plots from a field. The main thing is to enlist the support of a sympathetic and interested farmer. The results are usually striking and of definite value to the local agricultural community. Four plots, each of one-eighth of an acre are sufficient. They should be grazed by three dairy cows each for one or two hours daily.

The experiments with rabbits require the purchase or gift of say three wild grey females and one wild black male and of enough post and wire-netting of one-inch mesh and of ten feet height to surround a plot of about 35 by 25 yards. The wire must be sunk four feet into the ground to prevent escape, and a central mound of soil and brushwood should be provided for cover. Experiments with sheep or pigs require a larger expenditure of capital.

A school may undertake simultaneously two or three experiments like those suggested above, with groups of boys responsible for each, for perhaps three weeks at a time. If there is then a rota, all the boys become familiar with all the experiments and with the problems arising from them.

A certain degree of flexibility of time-table is, of course, necessary, but all the experiments which have been suggested have been thoroughly tried in practice, under school conditions. Mr. G. W. Olive, of Dauntsey's School, West Lavington, near Devizes, Wiltshire, will send reports about them to anyone who enquires of him.

If the circumstances of a school make it more convenient to experiment on arable than on pasture land, the following modifications may be made in the foregoing scheme.

Arable Land (Alternative to Pasture Land)

PLAN OF STUDY.

The references are to Pasture Land (see page 56).

(i) *The Plant as a whole:* Stet, but use as examples a cereal, clover or other legume, a "root" plant.
(ii) *The Shoot System:* (*a*) and (*b*) Stet. (*c*) Stet and add "A few fungi commonly found on crops should be studied in an elementary manner." (*d*), (*e*) and (*f*) Stet.
(iii) *The Root System:* Stet.
(iv) *The Chief Weeds of Arable Land:* Their identification and habits of growth.
(v) *Simple Physiology of the Plant:* Stet.
(vi) *Soil and Sub-soil:* Stet.
(vii) *Micro-biological Content of the Soil:* Stet.
(viii) *Insects:* Stet, but as examples of insect study: bee; mangold fly; frit fly; wire-worm; turnip fly.
(ix) *Worms:* Stet, and add "eel worms."
(x) *Birds:* Anatomy of the Fowl or Rook by dissection; life history.
(xi) *The Rabbit:* Stet. *The Mole:* delete.

OUT-DOOR PRACTICAL WORK.

Suggestions:—

Crop Rotations: A survey of crop rotations locally employed and a study of the determining factors in the use of such rotations.
Weeds of Arable Land: Their effect on crops, distribution, life histories, prevention and eradication. Vitality of weed seeds.
Fungus Diseases: A more detailed study of a few fungus diseases affecting crops.
Bee-keeping.
Bird Study: Observations on the bird visitors to arable land; habits (including migration); formation of a Bird Trust.
Manurial experiments.
Experiments with farm machinery and implements.
Labour costs: Investigation into labour costs and into the different operations of cultivation and harvesting.

10. EXAMINATIONS IN GENERAL SCIENCE SOME TENTATIVE PROPOSALS

ALTHOUGH we have tried not to think too much about examinations while making recommendations for the teaching of General Science, we have been conscious, all the time, of the great effect which they may have upon any attempt to put our proposals into practice in the classroom and the laboratory. As the end of our task approached we therefore gave considerable attention to this question and it may be worth while to record the results of our deliberations. We wish it to be clearly understood that many of the following suggestions are offered only in a tentative manner, in the hope that they may serve as a basis for further discussion. We do, however, feel sure that the usual type of examination paper gives undue reward to one kind of capacity—the ability to arrange information and ideas in essay form—whilst it almost ignores other equally valuable attributes which the candidates may possess.

Some of those who are closely in sympathy with our ideals think that making General Science an examination subject limits its scope and deadens its inspiration. Sir Philip Hartog, for instance, has said, " If ever there was a subject in which the go-as-you-please method of an enthusiastic teacher not bound to an examination syllabus was the best of all methods, I believe that you have it here. Therefore, make room for it in your curriculum, but impose no examination burden on the pupils." [1]

[1] Sir Philip Hartog, " Secondary School Examinations." Address to the Higher Education Meeting of the N.U.T., 1937 (obtainable from the N.U.T.).

To accept this conclusion immediately might, however, lead to unfortunate results. For some time to come examinations in specialised science subjects will probably continue to be set at the School Certificate level. Headmasters and others would thus have to decide between the claims of these more specialised courses and of those more generalised ones which, though better for the pupils, carried no examination credits. The desire for such credits exerts a powerful influence and, in effect, there would be many schools in which General Science would not be introduced at all. In other cases, only very inadequate time might be allotted to the subject. In addition some pupils might be led to feel that it was less important than other subjects, and that they need not " waste " much time or energy on it, since their " success " would not depend on proficiency in it. We believe therefore that external examinations in General Science should continue to be set until the whole question of the School Certificates is reviewed.

Nevertheless, we feel convinced that, even before more general reforms are introduced, examinations in General Science should depart from the conventional type. Merely to examine that subject in the usual way helps to introduce a rigidity and a formalism which tend to destroy the educational advantages of the courses we suggest. We therefore make the following proposals, which we believe would allow General Science to be examined without adversely affecting the spirit in which we would like it to be taught.

Our first proposal—it is not an original one—is that examiners in General Science should make full use of estimates of the candidates, supplied by those who have taught them. At present such estimates, when made, are far too often merely attempts by the teachers to prophesy the success of their pupils in the examination as it is. We suggest that an order provided for the examiner's guidance should be based on careful and systematic records of the pupils' progress and of their attitude and interests over the

period of their school life; it should depend upon their knowledge, the quality of their practical work, their out-of-school activities and any originality which they may have displayed. Estimates such as these should carry much weight in the examination, for they would possess much greater relevance and validity than judgments based only on the results of short written tests.

It may be objected that it is difficult, in an external examination, to pay much attention to teachers' estimates, since the quality of the work done in schools varies within wide limits, since the abilities of children in different schools vary, and since teachers may be biased. Yet children should not be penalised because of the supposed defects of their teachers, and the records we have mentioned above would, we believe, help considerably in grading the candidates, especially in borderline cases, whilst the written tests set by external examiners would help to overcome difficulties due to variations in standard among the teachers.

The written tests should be compiled to attain the following objectives:

(i) all the children should know thoroughly a limited range of facts and principles of fundamental importance;

(ii) all the courses taken in schools should cover parts of the three main sciences at least (and, preferably, parts of others as well);

(iii) this wide field should be combined with limited specialisation in certain directions; i.e. teachers of science should be able to direct their attention towards topics specially relevant to the environment of their school or to their own special interests and abilities (local specialisation).

In making proposals with regard to what might be called the machinery of an examination that would encourage teachers to aim at the above objectives, we have borne in mind the following considerations:

(i) Attention has lately been paid to "New Type" or "Objective" tests and much research has been expended on

their improvement (see page 73). In certain directions they possess important advantages over the usual essay questions. For instance, examiners can value the scripts with great reliability; their use in examinations helps to correct the injustice now done to children whose gifts are not of a linguistic kind; some of these New Type tests are particularly suitable for testing general information, the "knowledge about", which plays so large a part in General Science; and since as many as a hundred questions can be answered in an hour, adequate sampling of the syllabus is made easier.

(ii) As it is well to increase, as far as possible, the fraction of the total examination which can be marked objectively, we recommend the wider use of New Type tests. Nevertheless, we believe that these cannot as yet be easily employed to estimate certain aspects of scientific knowledge to which we attribute importance, such as the ability to marshal an argument in orderly sequence or to write down clear instructions for the performance of an experiment.

(iii) As it is advisable to separate the different things being measured, we recommend that more than one kind of paper be set. There would be a further advantage in adopting this suggestion since the technique of answering New Type questions differs from that of answering essay questions, and the candidates might be disturbed by differences in the style of questioning in the same paper.

Bearing all these points in mind, we suggest that General Science papers on the subject-matter of our Minimum Syllabus[1] be set in three parts:

Paper A (1 hour). A qualifying test, consisting of many short questions of a very easy kind, of which most might be New Type questions. In no case should the answer required consist of more than one or two lines of writing. There should be no choice of questions in this paper: the candidate should be expected to answer them all.

Paper B (1 hour). A New Type test of more difficult ques-

[1] See the *Teaching of General Science.*

tions, which would help to grade the pupils largely in accordance with their knowledge of facts. Here again, the candidates should be offered no choice of questions. This paper could be given to the candidates immediately after Paper A. Together, these two papers would require two hours.

Paper C (2 hours). An essay paper. There should be some choice of questions and ample time should be available for answering them. This would allow pupils to exhibit the knowledge they have gained while pursuing their special interests, or while studying the special subjects chosen in their school.

For examinations relating to the work included in the Extended Syllabus of the present Report, in which provision is made for schools which allot about eight periods a week for Science, two more papers would be desirable. One of these, a one-hour paper, should be of the B type. The other, of the C type, might require two hours. This last paper should be designed, *inter alia*, to allow pupils to exhibit the knowledge they have gained while pursuing their special interests or studying the special subjects chosen in their schools. It should include a very wide choice of questions.

Our reasons for making these suggestions will be obvious:

(i) Paper A would help to ensure that every pupil learns at least that minimum which corresponds in Science to the four fundamental arithmetical operations in Mathematics. It might also discourage certain schools from ignoring important branches of science. We suggest that the remaining papers of a candidate should not in general be considered unless he is awarded a high percentage on this one.

(ii) A paper as easy as Paper A would be useless for purposes of grading, since most of the marks obtained by the candidates would lie between 90 per cent. and 100 per cent., whilst many would obtain 100 per cent. For grading purposes the marks obtained on Paper B would be combined with

those on Paper C. The weight to be given to each should be a matter for careful consideration.

(iii) The B papers would be used mainly to test knowledge of *facts*. New Type tests can be used very effectively for this purpose.

(iv) Since factual knowledge would thus be tested separately, the examiners would be free to concentrate, in the C papers, on attempting to measure other factors such as power of writing good English, ability to devise new experiments and the power of selecting and arranging facts systematically. The markers would have to bear in mind that these, and not factual knowledge, were here being measured.

The scheme suggested would, we believe, help to ensure the elasticity, the freshness of approach, the contact with practical affairs, the ability to explore freely, which are essential to the worth-while teaching of General Science. It would probably be found that Papers A and B would be suited to all schools, but it is possible that more than one paper C would have to be set, on the Extended Syllabus at least, in order to provide for variation in the work done in different schools. We are strongly of the opinion that it should be possible for schools to present their own syllabuses for papers of the C type. This system is already in operation; and the more widely it is extended, the better.

Once again we desire to express our conviction that the grading of the candidates should not depend on the results of written tests alone, for there are many important qualities which cannot be valued adequately in this manner. Hence the grading by the external examiners should be carefully compared with that of the teachers who know the candidates, and all serious discrepancies investigated.

It will have been noticed that, so far, we have not mentioned practical examinations. This does not mean that we consider practical work to be of little importance, but we are

not convinced that the practical tests of the kind now common fulfil any useful purpose. They are often little more than disguised theoretical tests and, in any case, chance plays far too large a part in them. Above all, they do little to test ingenuity, ability to plan an experiment, manual skill or dexterity; they are scarcely *practical* examinations.

There still remains to be considered what is perhaps the most important and most difficult part of examinations: the choice and the manner of setting the questions. Let us first call attention to the importance of the rôles played by those responsible for setting the papers and by the Revisers and the Moderators. Knowledge of school conditions, sympathetic understanding of children, and experience of school teaching are more important than high academic qualifications. Unless those who do this work possess such qualities, the efforts of the schools may be thwarted and improvements in examinations will be slow.

Before we make specific suggestions, it will be useful to state some general considerations relevant to the problem:

(i) The teaching of science makes to education a number of contributions which are also made by other subjects. Our contribution to general intellectual development and to the building up of character may well be the most important part of our work. Yet, in a science examination, it is scarcely worth while to try to assess such qualities, partly because of the intrinsic difficulty of the task, and partly because that is not the best time or place for making the attempt. On the whole, it seems preferable, in the written tests of a science examination, to attempt to assess the degree to which pupils have managed to assimilate what is specifically dealt with in science lessons.

(ii) The ability to express oneself in clear English, and to select and to arrange relevant facts is as important in Science as elsewhere. We are not prepared to say what fraction of

the total marks awarded in General Science tests should depend on such powers, which must, quite incidentally, affect to a considerable extent the marks awarded to answers written in essay form. The recognition of this led us earlier to recommend retaining questions of this form in papers of the C sort.

(iii) Some critics have urged that much of what is learned by those who follow General Science courses is vague and superficial. This argument itself suffers from these defects, and overlooks the fact that, in any case, the scientific knowledge of School Certificate candidates is neither profound nor complete. In the specialised courses now common it has been usual to stop developing topics at a certain point. As a rule, no particular reason can be given for stopping there rather than elsewhere—tradition, rather than reason, usually dictates. The courses now proposed would lead us to change from a choice which is arbitrarily made to one which is rationally made. There is here no question of vagueness *versus* clarity, but of degrees of vagueness and clarity; and, after all, the pupils may understand just as clearly when the teacher deals with material chosen from a wide field as when he restricts himself to a narrow one. It is important for examiners to realise the nature of the difference, and the change in point of view must be reflected in the kind of question which is set.

In connexion with what has been said above, we believe it would be well if we attempted to list, in a tentative way, the specific features with which the teaching and examining of General Science are concerned. The course will naturally have produced in the pupils changes which it may be difficult to recognise. For instance, through our teaching they may have modified the way in which they behave in ordinary life, they may have become less dogmatic and less suggestible, they may have more respect for facts and be more suspicious

of unfounded hypotheses, they may have developed interests which will continue to grow in adult life. Such changes may be the most important results of our work, even though they are but by-products of it. In what follows we say little about them because we are here attempting to enumerate only those features with which teachers of science are directly concerned.

The list which is printed below is an analysis which may be helpful to examiners. It goes without saying that, while teaching, no one would separate out in this way the factors with which he deals. In order to make our meaning clearer we have, in each case, added a question designed to elicit an answer connected with that specific factor. These questions are no more than examples of the sort of thing we have in mind.

I. Acquisition of scientific information and knowledge.

(i) Knowledge of empirical facts.

e.g. Name two gases which are denser than air.

(ii) Power of reproducing verbally laws or principles.

e.g. State Boyle's Law.

(iii) Knowledge of technical terms, or of words used in science.

e.g. Explain the meaning of latent heat.

(iv) Ability to identify forms, structures, processes, and to state their functions.

e.g. A labelled diagram of a flower is given. The candidates are asked to name the parts and to state their function.

(v) Power of explaining verbally the meaning of a law or a principle.

e.g. What is meant by Conservation of Energy? Show how this conflicts with the idea of Perpetual Motion.

II. Development of scientific modes of thought.

(i) Ability to use scientific knowledge to explain facts of ordinary life—unification of experience, i.e. from facts to principles.

e.g. Explain (*a*) the occurrence of the blue flame that often appears over a coal fire, and (*b*) why soap forms a curdy precipitate with hard water.

(ii) Enlargement of experience by recognising in ordinary life instances of the operation of natural laws, i.e. from principles to facts.

e.g. Describe three experiments or observations which show that thermal radiation obeys the same laws as light.

(iii) Capacity to distinguish between facts and hypotheses.

e.g. Read the following passage. Then write down: (*a*) which of the statements are facts, (*b*) which are verifiable generalisations, and (*c*) which are mere statements of opinion.

(iv) Isolation of relevant facts from a complex situation.

e.g. A fairly complicated experiment is described, and the candidates are asked to point out which of the facts mentioned would be relevant to the solution of the problem considered.

(v) Ability to plan experiments, and to test statements.

e.g. (*a*) How can one find out that a certain muscle in a frog's leg is an extensor and not a flexor? (*b*) Devise experiments to test the following statement: "Saccharine is 500 times sweeter than sugar."

(vi) Ability to apply generalisations to new problems.

e.g. Two identical cubes of wood are sterilised and placed in separate moist chambers. Block A is kept sterile. Block B is inoculated with a fungus, which grows and thrives in the wood. How will the dry weight of these blocks probably compare at the end of three months? Why?

(vii) Ability to draw reasonable generalisations from experimental data.

e.g. Nine hundred seeds of a certain plant were divided into nine groups of 100 seeds each. Each group of 100 seeds was placed in a germinator; they were all kept in the dark under the same conditions. But each germinator was kept at a different temperature. The following data were obtained:

Temperature °C	6	8	11	13	18	25	30	35	39
Number of seeds which germinated	0	0	0	0	16	50	84	30	0

What generalisations could you draw from this experiment?

(viii) Ability to recognise problems which lend themselves to scientific treatment; and the contrary.

e.g. Which of the following statements could be investigated experimentally and in what way?

(*a*) Rain before seven, fine before eleven.
(*b*) A hot-water bottle airs a bed.
(*c*) Virtue is its own reward.

III. Application of scientific knowledge to socially desirable ends.

(i) Ability to recognise situations or unsolved problems in which scientific knowledge could usefully be employed.

e.g. (*a*) A woman planted some flower-seeds beside her house. The plants did not grow very well. The woman next door planted seeds of the same kind of flower. These plants grew very well. (*b*) A farmer had a flock of chickens. He noticed that on some days he would get many eggs and on other days he would get very few eggs. What kind of information would you need before you could explain these differences?

(*c*) It is proposed to locate a large carbide factory in South Wales, where many coal-miners are unemployed. What information would you find it helpful to have if you were called upon to advise on this proposal?

IV. Practical Powers or Skills.

Scientific knowledge involves power to use and to handle as well as power to "talk about things." Such skills cannot well be tested by written examinations. The candidates would have to be placed in specific situations calling for use of specific skills. The following factors can easily be distinguished :

(i) Development of manual skill and dexterity.

(ii) Ability to handle scientific material and apparatus (i.e. skill in laboratory technique).

(iii) Development of ideals of careful, neat and accurate work.

(iv) Ability to apply scientific knowledge to solve the practical problems of everyday life.

(v) Ability to devise experiments and to carry them through.

It will be noticed that, in the above list, Section I presents no particular difficulties to examiners. Examinations as they now are already measure this kind of knowledge fairly well. We believe that New Type tests would be more suitable here than essay tests, because they are an instrument which is more reliable and more easily controlled.

The material of Section IV cannot easily be tested by written examinations, but here the school records discussed earlier would give valuable information.

Papers A and B, in the scheme suggested, would test mainly the aspects listed under I, Paper C would test mainly the items listed under II and III.

In writing about examinations as we have done above, we have derived great help from *The Construction and Use of Achievement Examinations*, edited by Herbert E. Hawkes, E. F. Lindquist and C. R. Mann for the American Council on Education. It may be obtained from Messrs. George G. Harrap & Co. at 8*s.* 6*d.* net. A smaller manual for teachers which we can also recommend is the *Preparation and Use of New Type Examinations*, by Donald G. Paterson, published at 50 cents by the World Book Company, Yonkers-on-Hudson, New York. The latter publishers also supply collections of New Type tests, as do also The Cooperative Test Service, New York.

11. QUALIFICATIONS OF TEACHERS

Although the information collected in this Section will be familiar to many readers, it is possible that some may find it useful. We have therefore thought it well to add it as an appendix to our Report.—C. L. B.

In consequence of the increasing specialisation of University courses, it is now common for intending teachers to take a degree in one main and one subsidiary subject. Only seldom do they possess qualifications extending over the whole range of content desirable in science teaching in a secondary school. Some Universities are aware of the educational disadvantages of narrowly circumscribed courses. By offering more generalised degrees they have done something to encourage undergraduates to broaden the scope of their work. At Cambridge, for instance, candidates may take four subjects for Part I of the Natural Sciences Tripos. In London, candidates are allowed to take a General Honours Degree which includes three subjects such as Physics and Chemistry and Mathematics, or Botany and Zoology and Chemistry. Unfortunately it is not possible at that University to offer Biology as a single subject. Furthermore, these general degrees have not yet acquired the prestige of more specialised ones, and so far they are selected by comparatively few students.

Teachers whose academic studies have been mainly concentrated in one or two subjects are sometimes reluctant to broaden the scope of their work, for they feel that they will not be so successful in stimulating their pupils' interest and enthusiasm when they deal with somewhat unfamiliar material or with a subject of which their own knowledge is com-

paratively slight. These difficulties, though they exist, should not be exaggerated : in many cases teachers are dealing, very successfully, with subjects which they themselves began to study long after leaving the University. Many excellent and helpful books, both on subject-matter and on methods of teaching, are available, and, as a rule, it is not difficult to obtain advice. In some schools, where general science is taught and where there is a large staff, weekly conferences are held to discuss common problems and to enable the various specialists to help each other. Where this plan has been tried, those concerned always express themselves highly gratified by the results.

Besides such friendly collaboration with colleagues, some teachers who intend to introduce general science courses into their schools may wish to broaden their knowledge by attending special courses. They may find that the information in the present chapter is helpful, though it must be stressed that it is not complete and that courses and regulations alter from year to year.

It is important to note that the Board of Education grants full-time Studentships, without pay, to teachers of some experience to enable them to improve their qualifications. The Studentships may be for a period of one or even two years and may be of a value up to £200 per annum, according to the cost of the course. For the purpose of attending courses of study approved by the Board, it is possible also to obtain Grace Terms, on full pay and without loss of increment and pension rights. The Board of Education should be consulted for full particulars and conditions of Studentships and Grace Terms.

Additional Academic Qualifications. No one would suggest that it was essential for teachers to obtain academic recognition of the work they do in equipping themselves to teach General Science. Nevertheless, as some may perhaps find it helpful to give direction to their studies by aiming at an examination, a few possibilities are mentioned below.

Many Universities allow their graduates to take a Degree examination in subjects other than those which they offered at the Final First Degree Examination (e.g. London, Manchester, Reading, Belfast, Swansea). In some Universities special permission to sit for such examinations would have to be obtained. Since there is wide variation between the regulations that apply in the several Universities, enquiries should in each case be sent to the Registrar.

In some cases, as in Birmingham, properly qualified persons may be given permission to attend courses. A note certifying attendance and, possibly, that a satisfactory standard has been attained, may be given.

The University of London awards an (external) Diploma in Biology; the University College of North Wales and Sheffield University grant Certificates in Biology. In Sheffield the special courses for the certificate are held on Saturday mornings and in the evenings.

EVENING COURSES. In the larger towns, enquiries will often show that a number of evening classes, etc., are available. In London, Birkbeck College offers a complete curriculum of courses, all of them held after 6 p.m., many of which lead up to University Honours. In addition, many other Colleges associated with the University offer courses (e.g. in Botany, Geology, History of Science, etc.) which are held at times suitable to teachers. Full details of these courses are given in the pamphlet "Instruction courses for Internal Students in the Faculty of Science" (obtainable from the Registrar, University of London, W.C.1).

A few other examples will serve to show the kind of facilities which are available:

At Sheffield special short courses for teachers (in Physics, Chemistry, etc.) are arranged by the University.

At Manchester there are special two-term evening courses for teachers, in Biology, Horticulture, etc.

At Nottingham University College there are evening and Saturday morning classes in Botany, etc.

Bristol University has arranged University Extension Lectures and Public Evening Lectures for teachers beginning the study of Biology. Evening tutorial classes in that subject have also been held, some of them at considerable distances from Bristol, e.g. at Swindon.

There is little doubt that most Universities would be very willing to arrange special courses, in any subject desired by teachers, if there were any demand. It should also be remembered that Local Education Authorities usually welcome requests from teachers to arrange special courses; an attendance of about a dozen teachers is usually sufficient. Many courses of this sort have already been arranged, and those who have attended usually express high satisfaction with what has been achieved.

It may also be added that the Educational Advisory Board of the British Social Hygiene Council (Tavistock House South, Tavistock Square, London, W.C.1) is willing to organise courses in practical Biology, specially for science teachers, wherever there is a demand for them.

VACATION COURSES. A complete list of vacation courses for teachers, held in England, Wales and Scotland, is published annually by the Board of Education. This list should be consulted: it gives details of fees, dates of the courses, etc. A few examples of what was available in 1938 may be interesting:

Courses in General Science and in Biology, arranged by the Board of Education.

A course on Animal Biology at the Brighton Municipal Training College.

A Summer School in Practical Biology and Ecology at Exeter University College.

A Biology Course at Cork University College.

A Summer Course for teachers arranged by the Oxford University Department of Education.

A number of biology courses at Birmingham, Cambridge,

Sheffield, etc., arranged in connection with the Workers' Educational Association.

Courses in Biology, Laboratory Arts, etc., arranged by the Educational Handwork Association at Scarborough, Aberystwyth and elsewhere.

In Scotland, numerous Vacation Courses are arranged by the National Committee for the Training of Teachers. In addition, evening and Saturday morning courses in various branches of Science are regularly offered. At St. Andrews Summer School, a particularly full Biology course is available.

ASTRONOMY AND GEOLOGY. To teach the amount of Astronomy recommended in this report requires little beyond the study of a good elementary text-book and a few observations (with unaided eyes, or low-powered glasses). The Secretary of the Education Committee of the British Astronomical Association (303 Bath Road, Hounslow West, Middlesex) is willing to give advice to enquirers.

In Geology, some University institutions hold Saturday morning classes which are intended mainly for teachers. Evening classes are conducted by various technical colleges in different parts of the country. Summer Schools have been organised in some centres (e.g. Leeds, the Camborne School of Metalliferous Mining, the Glamorgan County Council). Such activities would undoubtedly be increased if the demand arose. London teachers, seeking to learn something of the subject or to increase their knowledge of it, might join the Geologists' Association. They would also find it useful to visit the Geological Museum, South Kensington. Others might join provincial geologists' associations, of which there are many.

Although nothing can fully replace field-work in Geology, teachers of the subject would derive help from the publications of the British Association Geological Photographs Committee, of which Professor S. H. Reynolds, of the University, Bristol, is the secretary. The British Association

has a Committee to consider questions affecting the teaching of Geology in schools. Professor A. E. Trueman, of the University, Glasgow, who is the Secretary of this Committee, is willing to advise enquirers on matters relating to his subject.

METHODS OF TEACHING GENERAL SCIENCE. There are available, of course, numerous text-books, books on the teaching of science, and articles in the professional journals. The Oxford Department of Education runs a summer school every two years, at which problems of teaching method are discussed. In addition, most Universities offer higher degrees in Education. The courses for these sometimes involve evening tutorial classes or lectures on science teaching, and they serve to put teachers in touch with sources from which advice on methods can be obtained.